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EDITORIAL

CO-ORDINATION OF ENTOMOLOGICAL RESEARCH IN THE COMMONWEALTH

ON page 21 *Tropical Agriculture* takes the unusual course of printing an author's reply to criticisms made in a review of his book.* This exchange of views serves not only to indicate the difficulties involved in the preparation of a book of this kind, but also to underline the author's reason for undertaking the work. In providing a source of reference and of concise information on most of the injurious insects of the British Commonwealth (excluding the British Isles, India and Pakistan) the author hoped that it would stimulate the preparation of a complete work on area problems. He points out that a pre-requisite for such a work is a series of regional handbooks and suggests that it might well be regarded as the duty of an entomologist to write one as a final contribution on the eve of retirement, or before departure after a long period of service. There are few entomologists who would find fault with such a suggestion, but it might well be argued that nowadays equally few would be in the fortunate position of being able to undertake this task. The quickening pace and ever widening sphere of scientific advancement create their own problems and inevitably lead to increased specialisation in a restricted field. Without greater establishments of entomologists than are

*The Injurious Insects of the British Commonwealth by J. W. Evans.

at present maintained by most Commonwealth territories, the possible tendency is for this specialisation to be directed into relatively few, and often unconnected, channels, and for the problem as a whole to be lost sight of.

The book under review seeks to avoid this by promoting a greater degree of co-operation between Commonwealth entomologists.

Appointment of I.C.T.A. Principal

It was announced by the Governing Body on 20th February that Dr. Geoffrey A. C. Herklots, M.Sc., Ph.D., F.L.S. had been appointed Principal of the Imperial College of Tropical Agriculture in succession to Mr. H. J. Page, C.M.G., O.B.E., B.Sc., F.R.I.C., who recently took up an appointment with the Food and Agriculture Organisation of the United Nations, in Rome.

Dr. Herklots was born in 1902 and educated at Trent College, Derbyshire, and at the Universities of Leeds and Cambridge. He is a B.Sc. with First Class Honours and an M.Sc. of Leeds University. At Cambridge, Dr. Herklots obtained the Ph.D.

He was Demonstrator in Botany at Leeds University from 1926 to 1928, and Reader in Biology at the University, Hong Kong from 1928 to 1945 although from 1941–45 he was interned by the Japanese in the Stanley Civilian Internment Camp.

He has written books on the flora and fauna of South China and on vegetable growing, and was editor of the *Hong Kong Naturalist* from 1930–41, and of the *Journal of the Hong Kong Fisheries Research Station*. In 1939 he spent six months in Nyasaland on secondment as Economic Botanist to the Nyasaland Nutrition Survey and in 1940–41 was seconded to the Government of Hong Kong as Scientific Adviser to the Food Controller. In 1946 Dr. Herklots was appointed Secretary for Development, Hong Kong and was in charge of the Departments of Fisheries, Forestry and of Gardens.

In 1948 Dr. Herklots returned to England and joined the Colonial Office as Secretary for Colonial Agricultural Research and of the Advisory Committee for Colonial Agriculture, Animal Health and Forestry. In connexion with his duties at the Colonial Office he paid an official visit to Jamaica, British Guiana and Trinidad early in 1950.

REVIEW ARTICLES, BOOK REVIEWS AND ABSTRACTS

GENERAL AGRICULTURE, AGRICULTURAL BOTANY

GRASS AND ITS UTILISATION IN TRINIDAD*

By

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PART I—INTRODUCTION

At the beginning of 1952 Trinidad and Tobago had a population of 656,300 (1), which is still increasing at the rate of 44 persons per day. This population, mostly of African and Asian descent, occupies a total land surface area of 1,980 square miles of which some sixty-three per cent. is agriculturally useless (2).

These two tropical islands enjoy a humid, insular climate which gives rise to a natural ecology of dense tropical rain forest, grass not being a natural cover. In the past few centuries the forest has been cleared from most of the agriculturally useful areas by the owners of large estates who planted sugar cane and cacao.

From the beginning of the nineteenth century, especially after the arrival of large numbers of indentured East Indian agricultural workers, the pattern of Trinidadian cultivation has somewhat changed. The large estates now exist together with an extensive peasant agriculture. It is therefore necessary to describe briefly the limited role of grass and livestock in both of these agricultural systems.

The Role of Grass and Livestock in Peasant Agriculture

The majority of peasants (0–10 acres) cut and soil their grass on the holding in inexpensively constructed cattle byres built of bamboo and tapia mud and thatched with various dried leaves, usually those of the carat palm, *Sabal glaucescens*. These individuals may or may not also tether their animals on roadside verges and other waste lands during the day whilst working either on or off the holdings.

The grass cut for soiling comes also from these same roadside verges and waste lands. It consists largely of Sour grass *Paspalum conjugatum*, Malojilla grass *Eriochloa polystachya*, Bamboo grass *Paspalum fasciculatum*, Savanna grass *Axonopus compressus*, Bahama grass *Cynodon dactylon* and

* A paper read before the December, 1952 F.A.O. Congress on Animal Production, Sao Paulo, Brazil.

Para grass *Brachiaria mutica.* These species will be found intermixed with various weeds and herbs as described by Paterson (3) all of which, with the possible exception of Para and Bahama grass, are of an inferior quality, especially since they are generally cut in the flowering or post flowering stages in order to obtain maximum bulk.

The peasantry for the most part think only in terms of bulk and are as yet insufficiently educated to realise the value of cultivating improved grasses for forage and grazing purposes let alone their correct utilisation. In the very few instances where grasses are grown by peasants they are of the forage type being either Elephant grass, *Pennisetum purpureum* or Guatemala grass *Tripsacum laxum.* From an economic standpoint the reluctance to grow grass on peasant holdings is justified. Even with the lower yields obtainable under peasant management the returns from rice, yams, sugar-cane, vegetables and other cash crops greatly exceed any possible income forthcoming from the same area of land were it to be cropped with forage or pasture grasses. Grass and livestock production are not therefore economic forms of land utilisation for the peasant, except in isolated cases.

Furthermore, economic animal production, especially clean milk, necessitates a large capital outlay far beyond the limits of individual peasants. Producer co-operatives could possibly overcome this difficulty but by and large the peasant is as yet unable to realise the benefits of co-operation at the producer level.

Peasant cattle, apart from those maintained chiefly for milk production, which will be discussed later, are kept chiefly for draught purposes. Manure and milk are incidental in the case of these animals which are poorly maintained receiving little or no concentrates. The diet of such animals is composed almost entirely of inferior wayside grasses either grazed or soiled on the holding.

Many peasants maintain a few goats for milk and meat production. Goats compared with cattle require a much smaller maintenance ration both in quantity and quality. As a consequence the goat is far more suited to the peasant economy for milk and meat production and those seen in Trinidad are healthy animals invariably in good condition. This is in sharp contrast to the average peasant cow which is under-nourished and invariably heavily infested with worms. Unfortunately the goat is not as popular as it ought to be partly because it fails to give its owner the social prestige attributed to the owner of an emaciated cow.

Grass and Livestock on the Estates in Trinidad

The two most extensive and economically important crops in Trinidad are sugar cane (82,000 acres) and cacao (100,000 acres). Sugar cane is produced partly by estates and partly by peasant farmers, whilst cacao is grown principally by estates. Coconuts and citrus together account for some 50,000 acres whilst other crops which are confined entirely to the estates include coffee, tonca beans, bananas and rubber.

The Sugar estates occupy most of the flat agriculturally useful land of the Colony and grow little or no forage grass for their livestock which are maintained purely for haulage work and manure production. These estates until quite recently kept herds of Zebu oxen *Bos indicus* for these purposes but now Water Buffalo *Bos bubalis* are preferred, since they are more efficient utilisers of the limited low quality forage. For exercise and limited grazing, savannas of varying extent are maintained. These savannas consist largely of Savanna grass *Axonopus compressus* and are usually situated in areas difficult to cultivate or of an inferior soil type. Soiling grass of a similar botanical composition to that used by the peasant is cut from the estate traces. In the sugar cane harvesting season, which extends from January to May, cane tops are also fed.

The estates growing cacao, citrus and coffee are mainly situated on undulating land principally in the Northern and Central regions of the island. On the estates a small number of cattle may be kept either for haulage, manure, or milking purposes or for any combination of these. Often a small savanna, consisting of savanna grass is available and soiling grass is forthcoming from the estate traces and clearings. These estates usually keep a number of horsekind, especially donkeys and mules, for transport. These animals are allowed to browse along the traces and under the tree crops wherever possible, but only in a very few cases is any grass grown especially for animal fodder.

Coconut estates are for the most part found in coastal areas. Grass and livestock play an unimportant role on these estates except in certain cases in Tobago, where beef and dairy cattle are allowed to forage in a haphazard manner. This limited use of coconut areas contrasts with many large coconut estates in other Caribbean islands where beef and dairy cattle graze in fairly large numbers beneath well managed coconuts of both the tall and dwarf varieties.

Milk Production in Trinidad

Only a few herds of cattle are kept in Trinidad specifically for milk production and they are confined to the Government Stock Farm, the Imperial College, some of the oilfields and sugar estates together with a few private individuals. The larger number of the island's cattle are peasant owned and many of these are kept specifically for milk production in units of one or two.

The sale of liquid milk in Trinidad is limited mainly to the small population and public institutions who own refrigerators, plus a few milk bars and manufacturers of ice cream. The Colony's small dairy industry producing milk under unfavourable environmental conditions and handicapped by the lack of correct managemental knowledge must also compete with heavily subsidised milk powder and condensed milk imported into the Colony in very large quantities.

At present one of the largest single overhead costs against fresh milk production in Trinidad is the heavy expense entailed in cutting and carting large quantities of fodder grass to the loafing pens for soiling. This is also the case in Hawaii where Beddows (41) found that cutting fodder grass by hand and carting accounted for half the costs of milk production. Either this procedure and the subsequent removal of manure must be inexpensively mechanised or the procedure as a whole be superseded by the successful introduction and management of pasture grasses and legumes. Cykler (7) has shown that mechanised harvesting of forage grass is possible under Hawaiian conditions where the soil and climate permit heavy machinery onto the land. This worker also indicated that efficient mechanisation is only possible by large units, either estates or co-operatives.

The Imperial College and Trinidad Department of Agriculture are approaching the problem by intensifying their search for suitable nutritious grazing grasses and legumes which can be inexpensively propagated.

A Milch Cow Suitable for The Wet Tropics

Endeavours to produce a breed of cow suitable for milk production in the Wet Tropics are still very far from a successful goal. There appear to be three different lines of approach to this problem. Firstly there are those hoping to achieve success by crossing *Bos indicus and taurus types*, endeavouring to select and fix the desired milk producing and heat tolerant characteristics in one animal. There are others who are striving for the same goal by selecting from within promising *Bos indicus* breeds such as the Sahiwal and Red Sindhi. Finally there are some who are convinced that economic milk production in the wet tropics will be solved only by selecting from the milking potential of either Water Buffalo or Milch Goats.

The size of an efficient animal found in a country is largely dictated by the quality and quantity of the available fodder resources of that country. Reference has already been made to the preference of Water Buffalo on estates on these grounds. The animal best suited for milk production in a wet tropical environment is obviously the one most efficient in converting the limited available low quality fodder resources into milk. In the case of the *Bos taurus* cattle it has been shown in temperate climates that if properly rationed for maintenance requirements according to body weight the Jersey is a much more efficient producer of milk than the Holstein (36). Furthermore, of all *Bos taurus* breeds the Jersey has been found to be the best to adapt itself physiologically to a hot climate (37). Were a *Bos taurus-Bos indicus* crossbred animal to be the answer for economic milk production in the wet tropics then it is most probable that the Jersey is the best *B. taurus* breed to use. On the Zebu side obviously the breed with the best milking potential should be utilised. In Trinidad the large numbers of emaciated, inefficient cows producing but a few pounds of milk indicate the difficulties inherent in a policy of crossing Holsteins with draught breeds of Zebu for economic milk production.

Duckworth (21) working with half and three-quarter Holstein—Zebu crossbred animals found that they consumed much less bulk than pure-bred *Bos taurus* cattle in temperate climates. Robinson (32) and other workers have found that there was no corresponding reduction in wet matter intake for *Bos taurus* cattle living under tropical conditions. Duckworth (34) has also indicated that *Bos taurus* cattle are more efficient than *Bos indicus* animals as utilisers of low fibre content roughage. However for every 1 per cent. increase in crude fibre content the digestibility of organic matter was depressed by 0.9 per cent. in the case of *Bos taurus* cattle and only 0.5 per cent. for *Bos indicus* stock. This indicates that with forages of a high fibre content there is little to choose between either type as regards the efficiency of the digestibility of organic matter.

Grass and Concentrates for Dairy Cattle

In most of the larger dairies the maintenance part of the ration comes chiefly from fodder grass, grown especially for the herd, together with a small amount of grazing. The fodder plots usually consists of Elephant grass *Pennisetum purpureum*, or Guatemala grass *Tripsacum laxum*, or Guinea grass *Panicum maximum*, or Para grass *Brachiaria mutica*, or Uba cane *Saccharum sinense*, and these in a very few instances may also include trailing legumes such as *Indigofera endecaphylla*, or tropical kudzu *Pueraria phaseoloides*.

For the production part of the ration imported and local concentrates are used by the larger dairy concerns. The peasantry on the other hand cannot afford to supplement the poor quality of their grass with concentrates except perhaps for a small quantity of locally produced molasses, coconut meal and rice husk. As a consequence the yields of peasant cows are low, an estimated average lactation figure being some 200 gallons.

The Possibilities of Increasing Trinidadian Animal Production

From the foregoing brief account it will be clearly seen that hitherto livestock and grass have played a relatively unimportant role in the Colony's economy. The last agricultural census in 1946 (1) revealed that there were some 40,000 cattle, including 3,000 water buffalo ; 32,000 goats ; 11,000 horsekind and 4,000 sheep in the Colony. The bulk of the Colony's dairy products are imported as is also most of the beef. The locally produced beef is of an extremely poor quality and comes almost entirely from old cows and draught oxen. Of the extremely few animals kept specifically for beef production few exhibit good beef characteristics.

Cultivated fodder and grazing grass is extremely limited in its extent in Trinidad. This is partially due to a lack of fundamental knowledge concerning both the agronomy and management of a few suitable and promising grasses so far available. However the greatest limitation to grass and livestock production in Trinidad is one of agricultural economics. Whilst sugar cane and other cash crops are so remunerative, grass and livestock will

continue to play a relatively unimportant role in Trinidadian agriculture. However, by improving the standards of management and utilisation both for the cultivated and inferior wild grasses, grass can contribute much more towards the Trinidadian larder than at present. As long ago as 1938 Paterson (27) evaluated the possible role that grass could play in tropical agriculture and with a few modifications his recommendations still stand.

PART II—GRASS AGRONOMY

Paterson (4) has divided West Indian grasses into three main classes in accordance with their general habit of growth :

(1) *Pasture or turf forming species :* comprising the more important bottom grasses capable of forming a more or less dense, close sward such as Savanna or Bahama grass.

(2) *Trailing species* which do not form any turf but produce a thick, tangled cover 1′–3′ in depth, composed of a profusion of intertwined leafy runners such as Para grass or Molasses grass, *Melinis minutiflora.*

(3) *Tufted or stool forming species,* mainly tall, erect cane like grasses such as Elephant, Guatemala and Guinea grasses.

Pasture Grasses

Of the turf forming species, Savanna grass is by far the most important in Trinidad and is the principal grass found on roadside verges, estate pastures and so on. The yield and nutrient quality of turf forming species are generally variable or fairly low, as is the case for Savanna grass. Of the newer exotic types, Smith (5) and other workers at the Imperial College have found that Toco or Tabaquite grass *Ischaemum aristatum* on both light and heavy soils, whilst equal to Savanna grass in palatability, has a considerable vigour of growth, which enables it to suppress weeds commonly associated with savanna grass pastures. Tabaquite grass also produces a considerably greater bulk of feed in comparison with Savanna grass. Promising results are also being shown at the Imperial College with *Brachiaria decumbens*, *Brachiaria brizantha*, and Nadi Blue grass *Dicanthium caricosum.* It is becoming increasingly obvious that an adequate knowledge of the management of these grasses, particularly the optimum carrying capacity per acre and the optimum duration of each grazing rotation, is most important to ensure the maintenance of a good sward.

At present in Trinidad all artificially established pastures are planted vegetatively. Many grasses in the wet tropics will not set seed or if they do, the seed is frequently difficult to collect and often non-viable. In view of the continual increasing labour costs the establishment of both pasture and soiling grasses is becoming more and more expensive. Any programme of work undertaken to extend and improve the grassland acreages in the wet tropics must overcome this fundamental problem.

Of the stool forming or forage type of grasses tried for grazing, Anthony & Hunter-Smith (6) have shown that Guatemala grass is unsuitable because the stout leaf midribs render the leaves extremely difficult for cattle to break off. Furthermore, uprooting occurs because Guatemala grass is a shallow-rooting species. Elephant grass, on the other hand, grazed at about 5′–6′ was readily eaten as has been found to be the case elsewhere (8). On the Government Stock Farm in Tobago, Guinea grass is satisfactorily rotationally grazed ; on the Government Stock Farm in Trinidad, Elephant grass is similarly utilised. Rotational grazing subsequently involves the immediate cutting of the uneaten stems preferably by machine. This must be undertaken in order to promote regrowth from the base of the plant, and to control weed species.

Fodder Grass

Of the trailing and stool forming grasses, Elephant grass is the most important in Trinidad, followed by Guatemala, Para and Guinea grass. The former two grasses are usually cut and carted to the loafing pens for soiling, whilst the latter two species are generally grazed. Uba cane appears to have decreased in popularity over recent years (22). Paterson (29) favoured Guatemala grass for Trinidad in spite of its inferior yield of nutrients per acre as compared to Elephant grass (23) and in spite of its susceptibility to rust (28). This preference was apparently largely due to the fact that the Elephant grass strains grown in Trinidad at that time were susceptible to Helminthosporium attack (29).

Moir (12) has pointed out that Guatemala grass is inferior to Elephant grass under good management. Where cultivation and manuring are likely to be neglected a case can be made out for the cultivation of Guatemala grass owing to its superiority in persistence and control of weeds. This is likely to apply particularly to peasant farmers.

Cultivation

Guyadeen (9) found that stem cuttings were the best material for propagating Elephant and Guatemala grasses. In both cases three to four node stem cuttings were much more satisfactory and promoted a better stand of grass than long cuttings of 2′–3′, planted in furrows. "Puddling in" long cuttings of Elephant grass on prepared soil in very wet weather is a much cheaper method of planting but has met with only fair success. As with these two grasses, Guyadeen (10) has also shown that stem cuttings for Colonial grass *Panicum maximum var. Coloniale* are better than rooted setts.

Guyadeen (11) found that the best spacing for Guatemala grass for maximum yields was $1\frac{1}{2}' \times 1'$ using two setts per hole rather than one. The planting distance must, however, depend on and be related to the tools and machinery available for subsequent intercultivation and harvesting. For hand weeding, the spacing of single cuttings could be fairly close, but for mechanical or animal tillage and harvesting, wider spacing is necessary. The standard widths at the Imperial College where machines are used are $2\frac{1}{2}'$–$3' \times 1'$–$1\frac{1}{2}'$

Manuring

Limited evidence available from work undertaken at the Imperial College has shown that whilst organic manures may be useful for grass they are not a limiting factor for growth, and should therefore be more usefully employed on other more valuable crops. Fodder grasses respond to applications of fertilisers particularly nitrogen (12), (13), (14), (15), (22) and (35). In Trinidad however the responses on certain soil types to phosphate and potash have to date appeared disappointing.

Harvesting

Paterson (16) has stated that Elephant and Guatemala grasses should be cut every 8–12 weeks on a rotational system in order to obtain the maximum yields of dry matter and crude protein. Guyadeen (10) found that comparing Elephant grass and Colonial grass crude protein value decreased as the grasses become more mature, but that the maximum yield of dry matter combined with crude protein occur much at the same stage as that advised by Paterson. Cowan (24) has shown that the yields of digestible protein per acre per annum are optimal for Guatemala grass if cut every 4 weeks. On the other hand Elephant grass yields did not differ whether cut at any stage between 4 and 10 weeks. No hard and fast rules can be given for the cutting cycle, since growth and composition depend upon so many factors, especially rainfall.

Work at the Imperial College would tend to show that the best height to cut Elephant grass is close to the base, though for Guatemala grass quicker regrowth is obtained if it is cut about 8″–9″ above the ground. However it is advisable to cut Guatemala grass above soil level once a year to promote regrowth from new buds at the base of the stems.

The Use of Legumes

The use of legumes as a stock feed either grown as a pure stand or in combination with grasses is extremely important in the wet tropics where protein is in short supply. At the Imperial College, *Pueraria phaseoloides, Centrosema pubescens, Calopogonium mucunoides, Indigofera endecaphylla, all* of which produce plentiful seed, are extremely promising. Mixtures of Elephant grass and Pueraria or Indigofera, and Toco grass and Pueraria have proved excellent when tried out on a limited scale under Trinidadian conditions. Further north, in Puerto Rico Elephant grass and Malojilla grass have been grown to advantage with Pueraria yielding much more nutrients per acre both in quality and quantity (33).

Soil Building Properties of Grass

The physical state of a soil containing a high proportion of sand and silt particles, typical of many parts of the tropics, is a very important factor in the growth and development of plants. Hewitt (17) has shown that on these soil types, perennial grass, such as Elephant grass over a period of four years will regenerate the crumb structure to a very high level, particularly if the colloidal material has not been depleted to a very low state by previous

cropping or if new colloidal material is added in the form of farmyard manure. Maximum aggregation takes place after approximately eight years whilst continuous cultivation destroys the desired crumb structure within four years. These findings in general appear to agree with those of East African workers (18).

Much more information is required from a West Indian standpoint. The implications of these findings are extremely important, since accepted policies, particularly for peasant agriculture are favouring mixed farming rather than monoculture.

PART III—THE UTILISATION OF GRASS IN TRINIDAD

Soiling and Fodder Grasses

Tropical grasses, irrespective of the method of utilisation, have been shown to improve soil structure (12). However, the annual removal of large quantities of fodder grass from the land quickly depletes the nutritional status of the soil. As Paterson (19) has pointed out not only is there a decline in the quantity of grass produced, but also there is a deterioration in the quality, especially the mineral content.

Of all the grasses exhibiting vigorous growth in the wet tropics fodder grasses with proper management yield by far the greatest quantity of dry matter and crude protein per acre (20). This is important especially in areas such as Trinidad where the quantity of available agricultural land is small. Furthermore, by utilising these grasses in the loafing pen, rather than allowing them to be grazed, the most efficient utilisation is effected. Destruction due to treading and spoilage due to defaecation and urination are eliminated.

Grass in the wet tropics yields a steady flow of nutrients throughout the year, thus enabling a more regular production of animal products than in the temperate zones. In areas such as Trinidad where there is a marked dry season causing a decline of some 20 to 30 per cent. in wet matter production, the dry matter and nutrient content of the same grass does not proportionately decline (19). This has also been found to be the case elsewhere (30), (31) and enables the animal during the dry season to consume more dry matter and nutrients per unit intake of wet matter.

Paterson in Trinidad, and other workers elsewhere, have stated that Elephant grass can yield up to 100 tons of wet matter or 15 tons of dry matter per acre per annum. This material when consumed in the loafing pen at the rate of some 80 to 100 lbs. per animal per day is sufficient to satisfactorily maintain up to 7 adult cattle per acre. Duckworth (21) has pointed out that Elephant grass is an unsatisfactory roughage for cattle partly because it entails heavy supplementation with concentrates due to its inferior nutrient content, and partly because the average tropical Zebu and grade Zebu animals appear to consume less bulk than *Bos taurus* cattle. It is therefore imperative that the bulk material offered to Zebu cattle should have the highest possible dry matter and nutrient content. Heneke (20) compared several soiling

roughages grown in Hawaii for dairy cattle. He has shown that wherever one forage grass excelled over another it was because the species in question possessed more dry matter and total digestible nutrients.

Grazing versus Soiling of Fodder Grasses

Whatever may be said in favour of fodder grasses, the present high costs of labour for cutting and carting them to the byre render them uneconomic. Due to their low dry matter content the cost per nutritional unit as presented to the animal is very high, a situation analagous to the feeding of bulky root crops in the temperate zones. Whilst some of these fodder grasses are unsuitable for grazing (6) others are grazed in various parts of the tropics, including Trinidad, with varying degrees of success. However it is generally agreed for various reasons that this method of utilisation is unsatisfactory and is only in vogue until more suitable grazing grasses become available.

Haymaking

Haymaking is not satisfactory in the wet tropics, since the best time for its preparation does not coincide with the availability of the material. Even if made in the dry season it soon goes musty when the atmospheric humidity increases. Harrison (25) has suggested that wilting would enable a higher dry matter content per unit of bulk to be presented to the animal. However wilting is known to lower the digestibility by some 3 to 5 per cent., but this should be compensated since by increasing the dry matter content the digestibility improves.

Ensilage

Paterson (39) has concluded that the best method of fodder conservation in the wet tropics is ensilage. The abundant supplies of wet matter of low dry matter content, and the humid climate are all factors militating against any method of fodder conservation, which involves drying. Cheap abundant supplies of molasses in these areas favour ensilage.

Some preliminary silage making investigations have been undertaken in Trinidad (42), but mostly on an experimental scale. The conclusions reached imply that in general the rules for silage making in the temperate zones apply equally for tropical conditions. McWilliam and Duckworth (43) carried out the making and feeding of Elephant grass silage on the field scale. Their work for the most part agrees with the earlier findings (42) but as might be expected on a larger scale the spoilage and nutrient losses were higher, but still approximately of the same order for silage made in temperate climates.

The Possibilities of Drying Grass in the Wet Tropics

Grass drying has been suggested as a means of fodder conservation in the wet tropics. In Trinidad the necessity for storing nutrients for the dry season is not a great problem since large quantities of cane tops are available. However, since the losses of nutrients during the processing of dried grass in the temperate zones are negligible as compared to some 35 and 8 per cent. for haymaking and ensilage respectively (38), it is worth while examining more closely the prospects of tropical grass drying.

Paterson (39) has investigated the matter and concludes that since only grasses with a high dry matter and crude protein content can be economically dried, the idea of drying tropical grasses is not feasible. These conclusions are shared by Shacklady (40) for the same reasons. The cost of removing large quantities of moisture coupled with the low nutritive value of the final product make the process uneconomic. With regard to the last point Shacklady has calculated that most tropical grass concentrates would scarcely be sufficiently nutritious even for maintenance requirements.

For meat and milk production the temperate zone farmer, favoured as he is by the environmental conditions, is recommended to concentrate upon the economic production of grass concentrates and leave available for his tropical counterpart the supplies of tropical oilseed residues, &c. to which the tropical farmer justly has first claim.

REFERENCES

(1) Statistical Digest for Trinidad and Tobago. 1951. *Trinidad and Tobago Government Printing Office.*

(2) A Proposed Land Allocation Policy for Trinidad. *Trinidad and Tobago Council Paper*, No. 56. 1944.

(3) Paterson, D. D. 1937. Forage Production in Trinidad. *Trop. Agric., Trin.*, **14** : 337–341.

(4) ——————. 1944. Grassland Management in the West Indies. *Imp. Bur. of Pasture and Forage Crops*, Bull. **31**, Part I : 7–29.

(5) Smith, R. B. 1950. Tabaquite Grass, *Ischaemum aristatum. Proc. of the Agric. Soc. Trinidad and Tobago.* **50** : 335–340.

(6) Anthony, K. R. M. and Hunter-Smith, J. D. 1945. Preliminary grazing trials in Trinidad. *Trop. Agric. Trin.* **22** : 143–145.

(7) Cykler, J. F. 1950. Mechanical Harvesting of Napier Grass and other Hawaiian Forage Crops. *Univ. of Hawaii Agric. Expt. Sta.* Bull. 102.

(8) Wilsie, C. P. and Takahashi, M. 1934. Napier Grass. *Univ. of Hawaii Agric. Expt. Sta.* Bull. 72.

(9) Guyadeen, K. D. 1949. Propagation and Management of some tropical grass and legume forages. *A.I.C.T.A. Dissertation.* Imp. Coll. Trop. Agr., Trin. (Unpublished).

(10) ——————. 1950. A Note on Colonial Grass. *Trop. Agric. Trin.*, **27** : 59–60.

(11) ——————. 1951. A Promising Fodder—Guatemala Grass. *Trop. Agric. Trin.*, **28** : 76–79.

(12) Moir, T. R. G. 1941. Tropical Fodder Grasses with special reference to Guatemala grass. *A.I.C.T.A. Dissertation.* Imp. Coll. Trop. Agr., Trin. (Unpublished).

(13) Notes of Current Investigations. 1952. *Malayan Agric. J.* **35** (2) : 112.

(14) Ellis, T. O. 1950. A Preliminary Survey of the Yields, Composition and Fertiliser Responses of Fodder Grasses. *Dept. of Science and Agric. Jamaica. Bull.* 41.

(15) —————— & Burrows, B. A. 1950. Results of Experiments on Yield, Composition and Responses to fertilisers of Napier Grass and Guinea Grass in Jamaica. *Dept. of Science and Agric. Jamaica.* Bull. 43.

(16) Paterson, D. D. 1933. Influence of Time of Cutting on Growth, Yield and Composition of Tropical Fodder Grasses. *J. Agric. Sc.* **23** : 615-641.

(17) Hewitt, C. W. 1949. Investigations into Soil Structure under Perennial Grass. *A.I.C.T.A. Dissertation.* Imp. Coll. Trop. Agr., Trin. (Unpublished).

(18) Martin, W. S. 1944. Grass cover in Relation to Soil Structure. *Emp. J. Expt. Agric.* **12** : 21–32.

(19) Paterson, D. D. 1939. The Cultivation of Perennial Fodder Grasses in Trinidad. *Trop. Agric. Trin.* **16** : 55–57.

(20) ——————. 1941. Grazing versus Soiling in the Wet Tropics. *Trop. Agric. Trin.*, **18** : 191–195.

(21) Duckworth, J. 1949. The Fodder Grass Consumption of Tropical Dairy Cows. *Trop. Agric. Trin.*, **26** : 24–25.

(22) Paterson, D. D. 1941. The Utilisation of Cultivated Fodder Grass in Trinidad. *Trop. Agric. Trin.*, **18** : 226–228.

(23) Kincaid, J. L. B. 1927. Growth and Composition of Fodder Crops in Trinidad. *A.I.C.T.A. Dissertation.* Imp. Coll. Trop. Agr., Trin. (Unpublished).

(24) Cowan, D. J. 1943. The Relative Yields, Digestibility and Nutritive Value of Elephant Grass and Guatemala Grass at different stages of growth. *A.I.C.T.A. Dissertation.* Imp. Coll. Trop. Agr., Trin. (Unpublished).
(25) Harrison, E. 1942. Digestibility Trials on Green Fodders. *Trop. Agric. Trin.*, **19** : 147–150.
(26) Heneke, L. A. 1943. Roughages for Dairy Cattle in Hawaii. *Univ. of Hawaii Agric. Expt. Sta.* Bull. 72.
(27) Paterson, D. D. 1938. Pasture and Fodder Crop Research in the Tropics. *Trop. Agric. Trin.*, **15** : 49–52.
(28) ——————. 1938. Further experiments with Cultivated Tropical Fodder Crops. *Emp. J. Exp. Agric.* **6** : 323–340.
(29) ——————. 1936. Cropping Qualities of Certain Tropical Fodders. *Emp. J. Exp. Agric.* **4** : 6–16.
(30) Cartmil, W. J. 1944. The Effects of Season, Stage of Growth, and Soil Type on the Chemical Composition of Grasses in the Queensland "Wet Belt". *Qu. J. Agric. Sci.* **1** (2) : 1–31.
(31) Schofield, J. L. 1945. Protein Content and Yield of Grasses in the Wet Tropics as influenced by Seasonal Productivity, Frequency of cutting and species. *Qu. J. Agric. Sci.* **2** : 209–243.
(32) Robinson, J. B. D. 1950. The Feeding of Dairy Cattle in Barbados. I. *Trop. Agric. Trin.*, **27** : 56–58.
(33) Loustalot, A. J. & Cernuda, C. 1948. Effect of Tropical Kudzu on Yield and composition of Forage Grasses. *Trop. Agric. Trin.*, **25** : 41–44.
(34) Duckworth, J. 1946. A Statistical comparison of the influence of crude fibre on the digestibility of roughage by *B. indicus* (Zebu) and *B. taurus* cattle. *Trop. Agric. Trin.*, **23** : 4–8.
(35) Innes, R. F. 1947. Notes on the Chemical Composition of some Grasses Grown in Jamaica. *Dept. of Science and Agric. Jamaica.* Bull. 35.
(36) Leitch, I. & Godden, W. 1941. The Efficiency of Farm Animals in the Conversion of Feeding stuffs to food for man. *Imp. Bur. Animal Nutrition.* Bull. 14. 1941.
(37) Alternate Husbandry. *Imp. Bur. Joint Pubs.* No. 6, 1944.
(38) Roberts, E. J. 1937. Grass Drying. *Agric. Council Report Series No.* 2.
(39) Paterson, D. D. 1938. Dried Grass Concentrate in the tropics. *Trop. Agric. Trin.*, **15** : 267–270.
(40) Shacklady, C. A. 1951. Tropical Grasses as Concentrated Feeding stuffs. *World Crops* **3** : 99–101.
(41) Beddows, A. R. 1944. Grassland Management in Hawaii. *Imp. Bur. of Pasture and Forage Crops.* Bull. 31, Part, I : 30–43.
(42) Paterson, D. D. 1945. Ensilage investigations with Tropical Forages. *Trop. Agric. Trin.*, **22** : 43–48.
(43) McWilliam, A. P. & Duckworth, J. 1949. The Preparation of Elephant Grass silage and its feeding value for Tropical Dairy Cattle. *Trop. Agric. Trin.*, **26** : 16–23.

(*Received for publication, December,* 1952)

BACKCROSSING. THE THEORY AND PRACTICE OF THE BACK-CROSS METHOD IN THE BREEDING OF SOME NON-CEREAL CROPS.

By MARY THOMAS. *Technical Communication No.* 16 *of the Commonwealth Bureau of Plant Breeding and Genetics, Cambridge,* 1952. *Pp.* vi + 136. *Price* 15/-.

A SITUATION which rather commonly faces the plant breeder is one in which an otherwise satisfactory variety of plant suffers from some critically important defect such as disease susceptibility ; how, then, is he to introduce genetic resistance without disrupting the complex and highly-selected genotype of the established variety ? The answer varies with the mating system of the crop in question but the most generally useful technique is the backcross method. Its success depends on the existence of material having a gene or genes for the character which it is desired to introduce and on the absence of unbreakable linkages between these genes and others for undesirable economic characters. Ease of application depends on certain other factors, such as number of seeds obtained per pollination (cotton is a good subject in this respect, wheat a bad one) and on the exact genetic nature of the introduced character (dominants are easier to handle than recessives or polygenes). Within this framework, the essence of the technique is to cross the two varieties, backcross the F_1 to the desirable commercial variety (the recurrent parent), select, backcross again and so on until a homozygous strain is obtained which approximates the recurrent parent in all characters except that introduced and maintained by selection from the donor parent. The classical example is Briggs' transfer of the dominant bunt resistance of Martin to several other Californian wheats ; indeed the method was first developed in cereal breeding and has only fairly recently been applied to other crops.

The book under review deals only with non-cereal crops and consists of a short introductory chapter on theory followed by long chapters on cotton, tobacco, the tomato and the potato. Thus, subtitle notwithstanding, there is a great deal of practice and very little theory ; the practice, however, is well expounded and the author has done an admirable work of careful and thorough compilation. Those chapters indeed make fascinating reading for the plant breeder by reason of the completeness of description—the crosses that failed, the strains that were lost, the variety trials destroyed by pests or bad weather ; they make an admirably complete and graphic picture of actual plant breeding operations with all their pains and disappointments. It is a pity that the theory of this important technique is so sketchily treated ; the introductory chapter might just as well have been omitted though it does at least give the references to the more important general treatments, notably those of Briggs and Knight.

The book is excellently made and printed though rather expensive at fifteen shillings for 136 pages—N.W.S.

PLANT AND ANIMAL NUTRITION

SAND AND WATER CULTURE METHODS USED IN THE STUDY OF PLANT NUTRITION

By E. J. HEWITT, B.Sc., Ph.D., A.K.C. *Technical Communication No.* 22 *of the Commonwealth Bureau of Horticulture and Plantation Crops, East Malling, Maidstone, Kent,* 1952. *Pp.* 241. *Price* 42/-.

The growing of plants in sand and water culture has for a long time proved an extremely valuable technique in many studies in plant physiology. By eliminating the numerous complex interactions that occur with growth in soil it is possible to concentrate on factors that can be controlled at will.

Of these factors, the significance of the micro-nutrients in plant growth has received considerable attention in recent years and increasingly delicate techniques have had to be developed to demonstrate the essential nature of such an element as molybdenum in the growth of higher plants.

In this book the author has brought together all the techniques that have been developed for growing in sand and water cultures a wide range of plants from lettuce and short term vegetables to tree crops such as apples and citrus. Part I deals with types of plant containers, their composition, capacity and drainage, the particle size and purification of the solid medium, sources of water and its purification and storage. An important section deals with methods of removing impurities from the nutrient reagents and with the compositions of a large number of nutrient solutions. Control of pH, the aeration of water cultures, influence of environment and various other minor but important features are dealt with in considerable detail.

In Part II, Dr. Hewitt describes the techniques he has developed at Long Ashton, based on Wallace's early work, for the preparation of materials for sand culture experiments on a large scale. As he says, the technique as it stands represents a stage of development but is not static and innovations are continually being introduced.

The presentation of the work is factual and up to date, and includes many unpublished results secured by private communication. Among these are to be found the methods of Evans and Maskell working at the Imperial College of Tropical Agriculture on the development of mineral deficiencies in cocoa.

In the description of their work and that of Greenwood and Posnette at W.A.C.R.I. one of the few errors that have been noted occurs. The author states (p. 143) " Seedling plants bearing only a few leaves were used.

These were raised either by sowing seed or by rooting leaf cuttings." In the first sentence "seedling" should be omitted. The continued description also fails to distinguish between the two groups of workers and is rather ambiguous. On p. 101, NH_4NO_3 (ionic) ratio should be NH_4/NO_3 (ionic) ratio.

These are minor points in a first class survey of what has become a wide field. The text is admirably illustrated by a number of half plate figures and photographs, and the extensive list of references runs to 30 pages. This book must prove invaluable to workers in all fields where use is made of sand and water culture methods.—D.B.M.

MYCOTROPHY IN PLANTS

By ARTHUR P. KELLEY. *Waltham, Mass.—The Chronica Botanica Co.; London, W.C.2—Wm. Dawson & Sons, Ltd.*, 1950. *Pp.* xiv + 223. 16 *text figures.* 5 *half-tone plates. Price* $4.86 (U.S.).

This book concisely presents a considerable amount of information about mycotrophy in Bryophytes, Pteridophytes and higher plants. This is a highly controversial subject, largely because so many writers have attempted to generalise from comparatively limited observations. The author cannot be exonerated from this fault. Although rightly stressing the need for more widespread surveys, to find out which plants are mycorrhizal, he makes (at the beginning of Chapter V) this sweeping statement: "It is unknown whether plants in nature have root hairs or mycorrhizae,—or neither; but there is enough evidence at hand to indicate that mycorrhizae predominate over root hairs in the majority of cases". Nor does he emphasise the paucity of reliable quantitative data on the benefits from the association (if any) gained by higher plants, under different soil conditions.

Dr. Kelley records that several fungi may form mycorrhiza with the same plant, but makes the unwarranted deduction that the species of fungus concerned is unimportant. He fails to appreciate the significant distinction, demonstrated by Melin, between the carbon substrates of mycorrhiza formers and litter decomposers amongst higher Basidiomycetes. The habit of quoting in foreign languages, sometimes without giving a clear indication of the meaning of the passage, is a drawback; though many readers will follow the French or German, comparatively few will be able to translate Italian.

Despite its flaws, the book should prove useful to students of mycotrophy. A reasonably full bibliography, giving references up to 1947, is appended. The plates and figures are good, and the book is attractively produced—W.T.D.

DAIRYING IN INDIA

By JAMES N. WARNER, M.Sc. *Issued by the Indian Council of Agricultural Research. Macmillan* 1951 *Pp.* 380. *Price* 25/-

To review a book entitled "Dairying in India" is perhaps somewhat presumptuous for one who has, as yet, never had the good fortune to set foot upon the sub-continent of India. However, the writer was able to compare Mr. Warner's work with several other texts on dairying and found this volume extremely interesting, informative and most easy to read. This book becomes the second of a much needed series of factual monographs now being issued by the Indian Council of Agricultural Research covering various aspects of Indian Animal Husbandry.

Mr. Warner can speak with authority upon dairying in India since he has been so actively associated with the subject at Allahabad. This book will be valued far beyond the confines of India, not merely because of the great paucity of literature dealing with tropical dairying but because of the actual merit of the work. The most experienced dairy technologists of the temperate zones would find much to ponder in the pages describing some of the ancient dairying practices of India.

Much excellent use has been made of tables but the reviewer greatly regrets the absence of photographs and lack of drawings. Certain chapters could have been greatly enhanced by one form or another of illustration. Perhaps the deficiency can be overcome in later editions.—J.R.H.

PESTS AND DISEASES

THE INJURIOUS INSECTS OF THE BRITISH COMMONWEALTH

By J. W. EVANS. *Commonwealth Institute of Entomology, London*, 1952, *Pp.* vii+242. *Price* £1. 10*s*. 0*d*.

It is stated in the Introduction that " the purpose of this work is to provide a source of reference and of concise information on most of the injurious insects of the British Commonwealth, with the exception of the British Isles, India and Pakistan." The undoubted value of such a book would, it is felt, have been greatly enhanced by a comparatively small addition to the number of references (which have been taken from the first 38 volumes of *the Review of Applied Entomology*), by a more careful selection of the references, and by avoidance of the rather numerous errors.

Insects are no respecters of political boundaries and much excellent work has been done outside the Commonwealth on pests that also occur within it ; references to such work should certainly have been included. Since they are not, the book cannot be used as a super-index to the Review, which would have been most valuable. To trace all the important references to a pest it will still be necessary to consult the index of every volume of the Review.

With regard to errors and omissions, the following have been noticed among pests of Trinidad and cacao pests. One can only assume that there is a similar number of mistakes among the pests of other countries and crops.

p.36 Under ' Comprehensive publications ' there is a surprising omission of *An economic entomology of the West Indies* by G. N. Wolcott, 1933 (22: 65)*

p.37 *Kalotermes brevis* (a dry-wood termite) can hardly be called a plant pest. The correct name of the Trinidad sugar-cane frog-hopper is *Aeneolamia varia* var. *saccharina*. Except for a few square yards grown for demonstration purposes at the Imperial College of Tropical Agriculture, no cotton is grown in Trinidad ; *Dysdercus* cannot therefore be called a principal insect pest in Trinidad. The correct name of the cacao beetle is *Steirastoma breve* (36 : 71). The note on the breeding places of *Anopheles bellator* and *A. aquasalis* is incorrect—*bellator* is the bromeliad-dwelling forest insect and *aquasalis* the brackish water species. Important omissions are *Scapteriscus vicinus*, *Selenothrips rubrocinctus*, *Cosmopolites sordidus*, *Diatraea* spp., *Rhynchophorus palmarum*, *Atta cephalotes* and *Acromyrmex octospinosus*. All these are at least as important in Trinidad as *Castnia licoides*, the only insect correctly mentioned in this section.

*References are given, as in the book itself, to the volume and page numbers of the Review of Applied Entomology.

p.74 *Selenothrips rubrocinctus.* An important reference to thrips-resistant varieties of cacao should be included (32 : 26).

p.82 *Toxoptera aurantii* is not a vector of cacao virus either in West Africa (34 : 102, 37 : 85, 37 : 315) or in Trinidad (38 : 309).

p.83 There are no references to recent and successful control measures against *Aeneolamia varia* var. *saccharina* (e.g. 37 : 83).

pp.92-97 The information on coccid vectors of cacao viruses, both in West Africa and Trinidad, is incomplete, only *Ferrisia virgata*, *Pseudococcus concavocerarii*** and *P. njalensis* being correctly mentioned for West Africa and none for Trinidad. Many other vectors are actually known, see 38 : 309 for Trinidad and 37 : 85, 38 : 378 for West Africa. (Still more West African vectors are listed in 39 : 46, but, as stated in the introduction Vol. 38 of the Review was the last volume consulted.)

p.99 *Mesohomotoma tessmanni* is not a vector of swollen shoot (34 : 102, 37 : 85, 37 : 315).

pp.103–106 More up-to-date information on cacao Mirids in West Africa is given in 35 : 87 and 37 : 85. The attack of *Bryocoropsis laticollis* is not confined almost entirely to the pods, whereas that of *Helopeltis* sp. is. Most of the damage done by *Sahlbergella* and *Distantiella* is due to infection of the lesions by the fungus *Calonectria rigidiuscula* (37 : 70).

p.116 The cacao beetle, the correct name of which is *Steirastoma breve* (36 : 71) is actually more serious in Grenada than it is in Trinidad (27 : 25).

pp. 150–151 *Acromyrmex octospinosus* is, in Trinidad, a pest of many other crops besides cacao, on which *Atta cephalotes* is equally or more important.

p.176 *Castnia licoides* does not occur in the Lesser Antilles, nor can the statement that it does so be found in either of the reviews quoted (19 : 627, 36 : 71) or in the original articles to which they refer.

pp.177–178 *Diatraea lineolata* does not attack sugar cane either in Trinidad or anywhere else.

p.184 *Megastes grandalis* occurs in Trinidad but not in the Lesser Antilles, a fact that is specifically stated in the publication to which the review quoted (36 : 71) refers.

**Actually it seems very doutbul if *P. concavocerarii* has been found to transmit any of the strains of cacao virus in West Africa. The Review reference (37: 85) to its having done so is incorrect ; reference to the original paper (*W.A.C.R.I. Ann. Rept.* 1946–47) shows that it failed to transmit in any of 18 tests. On the other hand *W.A.C.R.I. Ann. Rept.* 1948–49 includes this species in a list of 12 pseudococcid vectors. Yet Posnette in a still more recent paper (*Ann. Appl. Biol.* 37, p. 378, 1950) states that it failed to transmit, and only records 11 vectors.

It is true that the author has forestalled the foregoing criticisms by stating in the introduction that it is inevitable that a number of species of local importance has been overlooked, that some insects which have been recorded as pests no longer belong in this category, and that errors have been made and all sections are not equally complete and up-to-date.

The value of a reference book of this type is, however, in direct proportion to its accuracy and completeness and it is in no spirit of destructive criticism that these errors and omissions have been pointed out. Rather it is to be hoped that, before a second edition is issued of what could be a most useful publication, the Government Entomologists of the territories concerned will be asked to assist in its revision—T.W.K.

The reviewer has invited the author of this publication to comment on the above. We print his reply below. (Both review and reply appear with the permission of the author and of the Commonwealth Institute of Entomology)—Ed.

No one can be more aware than the author of the shortcomings of the book reviewed. Although its preparation was begun under favourable circumstances, it was completed under difficult ones. This was because the author changed his employment at a time when the manuscript consisted solely of notes based on extracts taken from *the Review of Applied Entomology*. In his new post very limited time only has been available for outside activities and none for those requiring prolonged attention.

The reviewer suggests that before a new edition is issued, the Government Entomologists of the territories concerned be asked to assist in its revision. It was appreciated by the author that real accuracy could be achieved only if regional sections of the manuscript were submitted prior to publication to entomologists having special local knowledge. Failure to do this was not due to oversight but because it was realised that it would mean more additional work than could possibly be handled under the changed circumstances. While lack of time is the principal reason for omissions, and errors due to initial carelessness, another will have been the method of preparation adopted. It was assumed, and the assumption was based on the author's own knowledge of certain regions, that a search of abstracted literature, covering a period of nearly 40 years, would disclose accounts of investigations concerned with all insect pests of importance undertaken in every territory where they occurred. Further, that such investigations would have been the subject of separate papers, which would have been noted as such in the Review. The fact that the system has failed to give the correct picture of the insect pests of Trinidad suggests that although much research may have been undertaken there, but little information is readily available and that there is a need for an up-to-date comprehensive work.

The Reviewer is of the opinion, and it is one shared by the author, that the book would have been more useful if compiled on a world basis. Lack of

time prevented this being undertaken. It was, however, never intended as a " super index to the Review " but merely to provide a summary of information on Commonwealth problems for the information and interest of Commonwealth Entomologists.

Wolcott's work on West Indian Insect Pests was overlooked since it was not published within the Commonwealth.

Several of the insects listed as omissions, as for instance, *Cosmopolites sordidus*, were left out purposely as explained in a footnote, and reference to the occurrence of the pest in Trinidad is given on page 125.

While regretting that incorrect names are given for the Sugar Cane Froghopper and for the Cacao Beetle, the fact remains that all names were checked by specialists. The first-named insect was not inadvertently placed among those of major importance and the opening paragraph of the section dealing with it make it clear that the author was aware that it is now under control. It was included with the major pests because of its special interest as being the insect to have received more prolonged and extensive investigation than any other in Trinidad. The Reviewer also draws attention to the omission of recent references to successful control work with this pest. These were not missed but omitted since they deal with chemical control and hence lie outside the scope covered*.

The Reviewer states that two insects have been incorrectly recorded as virus vectors. This error is doubtless due to the system of compilation which provided for the notice of positive information (and both insects *have* been recorded as actual or potential vectors) but failed to provide for the noting of corrections at a later date. Similarly positive information was recorded to the effect that *Diatraea lineolata* was a minor pest of sugar cane, while later contradiction was evidently missed.

Exception is taken to the inclusion of *Dysdercus* spp. among the " Principal Pests ". Examination of similar lists for other countries will disclose that many of those given may not at present be economically significant, but are nevertheless all of some special entomological interest.

The Reviewer's strictures suggest that he considers that it would have been better had the book not been published at all, but to wait for perfection may mean completing nothing ; and fruitful activity is often provoked by well intentioned though imperfect efforts.—J.W.E.

**The Reviewer has added the following—Ed.*

The Reviewer regrets that he overlooked the statement, in the introduction to Part 3, to the effect that references to chemical control have been deliberately omitted " because the literature on the subject is so vast as to require separate treatment and because of the rapid rate of recent development in this field ".

Nevertheless he thinks that it would have added to the value of the book if at least the more recent references to successful chemical control had been included.—T.W.K.

MOSQUITOES OF THE ETHIOPIAN REGION

Part I—By G. H. E. HOPKINS. *London, British Museum (Natural History)*, 1952. *Pp.* viii + 355. 211 *figures*. *Price* £2. 6*s*. 0*d*.

The introductory chapters of this book, on ecology, external morphology and technique, show little change from the first edition (1936) except for the addition of footnotes by P. F. Mattingly. In the principal part, however, on the taxonomy and breeding places of mosquito larvae other than *Anopheles*, the number of species dealt with has been increased from 248 to 334. Much of the new material has been acquired as a result of research on Yellow Fever during recent years and information available up to September 1951 is included.

The book is very well produced and no misprints have been noticed. The known geographical distribution of most species is omitted altogether and even where localities are mentioned they are often obviously incomplete. This seems a curious omission in an otherwise excellent publication.—T.W.K.

THE HORSE-FLIES OF THE ETHIOPIAN REGION

Volume I—By H. OLDROYD. *London, British Museum (Natural History)*, 1952. *Pp.* ix + 226. 318 *figures*. 15 *distribution maps*. *Price* £2. 0*s*. 0*d*.

This is the first of three projected volumes dealing with Ethiopian Tabanidae. Vol. 2 will comprise the remaining genera of the subfamily Tabaninae and Vol. 3 the subfamily Pangoniinae.

The present volume deals with 5 species of *Hippocentrum* and 171 species of *Haematopota*, of which 46 are here described for the first time. The keys and descriptions refer only to the females, since there are comparatively few species of which the males, which do not bite, are known.

There is little or no evidence that these horse-flies are directly concerned with the transmission of any disease, for no development of a pathogen has been demonstrated in them. However, it is almost certain that they are responsible for the mechanical spread of diseases among gregarious animals.

It is, of course, only interrupted feeding that is dangerous in this connection, for there can be no transmission of disease if a fly gorges itself on one animal and does not feed again until after any pathogens that it has picked up have died. Very little, however, is known about the feeding habits of Tabanidae on animals.

There is a much greater number of species of *Haematopota* in the Ethiopian than in any other region and the genus, with its absence of clearly marked subgenera or groups of species, appears to be in active evolution. The author suggests that it may be evolving *pari passu* with the ungulates, another comparatively modern group of animals, which are its main source of food.—T.W.K.

DE PLAGEN VAN DE CULTUUR-GEWASSEN IN INDONESIE

(The pests of cultivated crops in Indonesia)

By L. G. E. KALSHOVEN. *Van Hoeve, The Hague*, 1951. *Two volumes, total pp.* 1065. 16 *coloured plates.* 579 *figures. Price* £7. 4*s.* 0*d.*

This is an outstanding contribution to the entomological literature of the Far East. The pests dealt with range from Nematodes to Elephants, though naturally the greater part (850 pp.) is devoted to insects. For all the more important pests a brief description is followed by an account of the damage done and suggestions for control. Parasites and predators are dealt with in their systematic position, as well as being briefly mentioned in the account of their hosts. The line drawings, the number of which must run into thousands (since many of the 579 "figs." actually contain up to twenty separate illustrations), are excellent. So are most of the photographs of damage, but a few of the coloured figures are perhaps not quite up to the same standard. Surely no Syrphid has the venation depicted for *Asarcina aegrota* in Plate XIV, fig. C ?

The only real criticism is of the system of references. These are given rather irregularly, sometimes at the end of a family, sometimes after two or three families, and sometimes after only one species has been dealt with. Both the names of authors and of publications are over-abbreviated and though there is a list of abbreviations at the end of Vol. II, it is not complete. For instance, though RAE is doubtless *the Review of Applied Entomology*, what is Md. Plz.? Neither of these appears in the list of abbreviations or, for that matter, in the *World List of Scientific Periodicals.*

For the benefit of those who (like, let it be confessed, the reviewer) have little knowledge of Dutch, an appendix is provided giving the English translation of the legend to the plates and text-figures.—T.W.K.

KRILIUM AND OTHER SOIL-AGGREGATING CHEMICALS*

By

W. P. Martin and R. Q. Parks

Reports on Krilium, a new soil-aggregating material, have aroused a great deal of interest and speculation among farmers and professional agricultural workers.

Initial tests show, when this material is properly applied, that it can change tight, heavy clays into soils of good, friable crumb structure. Furthermore, this desirable granulation is stable and long-lasting.

Krilium is the trade name of one of a family of complex organic chemicals developed by the Monsanto Chemical Company. Formulations of this compound have just been placed on the market in limited quantities, and larger amounts should be available by the end of this year.

Soil-aggregating agents are also being developed and marketed by other chemical companies. Tests on some of these other materials are just being started by several of the state agricultural experiment stations and the U.S. Department of Agriculture. It is therefore not possible as yet to comment in detail on the effectiveness of these materials. The evidence from preliminary tests clearly shows, however, that certain of these new soil-aggregating agents are not as effective as Krilium.

None of these soil-aggregating agents are fertilisers. They affect plant growth indirectly through the improvement of soil structure and tilth.

The friable, loose, crumb structure so characteristic of good garden soils is the result of aggregation or clumping together of clay particles in the soil. Such good tilth is essential for best growth of plants. It allows faster penetration of rain, with less erosion and better water conservation.

Favourable structure also improves soil aeration, favouring the growth of plant roots and soil micro-organisms. Soils in good tilth drain more rapidly in the spring, plough and cultivate more easily, and permit seedlings to emerge quickly and easily—since they are less prone to surface crusting.

Soil organic matter, manure, and crop residues are all decomposed in the soil by mico-organisms, with the production of gums or cementing agents. These glue-like compounds bind silt and clay particles into water-stable " crumbs " or aggregates.

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*Reprinted from : " Crops and Soils ", Aug.–Sept., 1952, pp. 17-18 & 46.

Generally speaking, the more rapidly organic matter decomposes in the soil, the greater the production of soil-aggregating compounds. But their effect is not lasting. These natural soil-aggregating gums are, in turn, rapidly decomposed by other soil micro-organisms. Hence it is necessary to add large quantities of organic matter at regular intervals in order to maintain good soil tilth.

On the other hand, these new synthetic soil conditioners act almost instantaneously, and the effects are long-lasting. Tests with Krilium have been under way for only 3 years, but the loss of soil aggregation has been small during this period.

Tested 3 Years

Field and laboratory tests with Krilium at the Ohio Agricultural Experiment Station are now in their third year. Among the crops being tested in carefully controlled field and green-house experiments are field and sweet corn, oats, soybeans, sugar beets, red beets, turnips, carrots, potatoes, grass and legume seedlings, greenhouse tomatoes and roses.

Yield increases were recorded in many instances, though not all of these crops responded to soil-conditioning treatments. In one representative experiment, field corn was grown on Miami silt loam subsoil which had been treated by disking in 400 pounds of Krilium per acre. The treated areas yielded 15 bushels of corn per acre more than the untreated soil—both with generous additions of fertilizer.

Oats Increased 40%

Oats planted as a nurse crop for alfalfa on Crosby silt loam yielded 40 per cent. more on the Krilium-treated soils.

Marketable carrots were increased 21 per cent. in treated Brookston clay loam. Potatoes and sugar beets in the same soil did not show significant yield increases, but dug easier and came out of the ground clean.

Corn and red beets showed marked growth responses to treatment of Paulding clay with Krilium, and they matured more quickly. No toxicity or adverse growth effect has been noted in any of these experiments.

During the 1951 growing season, field experiments were conducted by U.S.D.A. workers on saline and alkali soils in California, to find out if Krilium would aid in reclaiming these soils or enable them to produce more satisfactory crop yields. Favourable results were obtained, with remarkable increases in the germination and stands of corn. In one case, yield increase was as much as five-fold.

This experiment illustrates one of the side benefits of synthetic soil-aggregating compounds in agricultural research. With these materials, it is now possible to produce various levels of soil structure improvement.

Management treatments can now be evaluated in terms of how much benefit is due to improved soil structure, and how much is due to chemical or fertility effects.

Other experiments with soil-conditioning materials were conducted in Alabama, Tennessee, Pennsylvania and Wisconsin. Germination of cotton was greatly improved by Krilium treatment of heavy clay soil in Alabama. The work of the season is not yet fully evaluated, but the material has been shown to produce definite improvement in the physical character of heavy clay soils, thereby encouraging greater root development. In only a few instances was any failure to obtain marked improvement in soil aggregation observed.

Should be Spread Dry

In agriculture and home gardening, Krilium should be spread dry on the surface of the soil and then mixed thoroughly into the soil by means of a rotary tiller, disk hoe, or rake. Adding sufficient water to soak down the treated soil volume helps to achieve maximum stability of the soil aggregates. The loosening, working and mixing of the soil is essential. Soil-aggregating agents themselves cannot loosen up soil. They merely stabilize the open, crumbly structure produced by mechanical working of the soil. Rates of application found to be effective range from 400 to 2,000 pounds of pure Krilium per acre, when incorporated into soil to a 6-inch depth. Perhaps 1,000 pounds per acre will be a representative rate, when the material is incorporated throughout the entire plough layer. Formulated products prepared for easy application will have to be added at higher rates to give these quantities of "active" Krilium.

Prevents Soil Crusting

One possibility for decreasing this rate would be to treat only the surface half-inch or inch of soil, which would prevent crusting during the germination of meadow seedlings. For row crops, experimental tests are being made by treating only a narrow band of soil above the seed row.

Until some of these economies of material can be proven, possibilities of widespread agricultural use of synthetic soil conditioners do not seem great in view of current introductory prices.

There are, however, a number of specialized agricultural uses for which synthetic soil aggregation should be most practical. Examples are preparation of potting soils, greenhouse production of flowers and vegetables, and improvement of home flower beds and vegetable gardens located on heavy clay soils. Possibly certain market garden areas where high-value speciality crops are grown will also find it profitable to use these materials.

Another promising field of use for these soil stabilizers is the treatment of soil on road cuts and similar engineering projects. In this case, the material is not mixed with the soil, but is used as a surface film to prevent erosion on the steep slopes, while a grass sod is being established. In Ohio tests, erosion

was non-existent on Krilium-treated banks, and grass seedlings became established more quickly than on slopes not treated.

Experiments which spray seed, fertilizer and Krilium all at one time onto the sides of roadcuts are being followed with great interest by highway engineers throughout the country.

Even if synthetic soil aggregants come into general agricultural use, they will not do away with the need for natural soil organic matter. These aggregating agents add no fertility and furnish no food for soil micro-organisms. Manure and crop residues do. Furthermore, aggregating agents cannot be applied easily to heavy subsoil layers, which plant roots often penetrate and open up with ease.

Farmers will still need to follow good crop rotation, fertilizer, and management practices, including the turning under of crop residues and other organic materials.

INTERACTIONS OF SOIL AND ANTISEPTICS*

By

I. Szladits

Interactions between soil and organic compounds used to destroy plant pathogens may reduce or modify the effectiveness of the compounds and cause significant changes in soil properties. The matter is receiving considerable attention from research workers, and a summary of some of the results obtained is given below.

Effect of Moisture and Temperature on Dissipation of Antiseptics

Hagan (1941) and Hanneson (1945), investigating the movement of carbon disulphide in the soil, found that penetration of vapours decreased with increasing moisture and was lowest at a level near water capacity. The permeability approached zero in a porosity range of 26–29 per cent. and compaction, such as ploughsoles, causing changes in porosity seriously hampered the distribution of vapours. Increasing clay content decreased permeability, whereas each 10°C. rise in temperature increased the movement of vapours by about 50 per cent. As fumigation after heavy rains or irrigation is likely to become ineffective in the cultivated layer, injection should preferably be made below the tilled surface.

Richardson *et al.* (1943) reported that while penetration of methyl bromide was easy into dry or moist soils, it was almost completely prevented at a moisture content near water saturation.

Dispersion and retention of chloropicrin and DD-mixture in the soil were studied by Schmidt (1947). The most even distribution occurred at a moisture content of 20–25 per cent., the movement of vapours being least rapid and retention longest at contents near water-holding capacity. The movement, particularly of DD, in dry soils was mainly upwards and in wet soils downwards. Increasing the depth of injection from 6 to 12 inches extended the time of retention, but reduced efficiency near the surface. Chloropicrin dispersed better and was retained longer than DD, and the high initial concentration of vapours at the time of injection decreased slowly, but at a rate sufficiently rapid to prevent the building-up of strong toxic levels in the cultivated layer.

The deepest soil penetration was observed with DD (Stark and Lear, 1947), which was found by Allen and Raski (1950) to disperse in sandy loams at least 8 inches laterally and 12 inches below the injection point. The action of the chemical was most powerful when injected 6 inches below the surface, but dispersion was limited and the efficiency of a given dosage much reduced in soils of high clay or organic-matter content.

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The dissipation of chloropicrin from soils of different texture greatly increased with temperature (Wilson, 1943). Complete disappearance of 2 millimetres injected 4 inches deep occurred in 28 days at 12°, in 16 days at 24°, and in 9 days at 32° C.

McClellan *et al.* (1949) reported that volatile fumigants, applied at soil temperatures ranging from 45°–101°F. and at moisture levels of 7–20 per cent., were retained longest in wet soils at low temperatures. Toxic effects on the tested organisms were, however, more rapid and efficient at 82°–98°F. than at lower soil temperatures.

The rate of adsorption of chloropicrin was apparently not influenced by the degree of soil aggregation and pH, but it decreased with increasing soil temperature and in presence of moisture (Stark, 1948). There was a high positive correlation between increasing clay percentage or decreasing particle size and vapour adsorption by the soil ; nearly 10 per cent. dry weight was adsorbed by colloidal clay as compared with 3.2 per cent. by clay, 0.8 per cent. by silt or 0.18 per cent. by sand. Dry soils sorbed more methyl bromide than wet soils (Chisholm and Koblitsky, 1943), and sorption by dry peat was 4.5 times, and by dry clay soil 2.75 times, as much as by sand.

Effects of Colloids on Adsorption

Shchepetilnikova and Cheremisova (1937) reported that the amount of chloropicrin adsorbed by various soils was in direct proportion to the organic-matter content of the soil, and the chemical appeared to mineralize some of the organic matter. Lear (1951) found that several fumigants and particularly methyl bromide were effective mainly in sandy soils and at moisture and temperature levels ranging above 18 per cent. and 75°F. respectively, but failed in organic soils or at low moisture or temperature.

Siegel *et al.* (1951) reported that 1–3 dichloropropane and 1–2 dibromoethane were subject to strong adsorption by colloidal organic matter, and their diffusion was adversely influenced by a dry or saturated condition of the soil.

Maximum Efficiency Conditions

Adsorption studies by Fuhr *et al.* (1948) and Lubatti and Smith (1948) also indicate that low adsorption of volatile antiseptics is obtained with medium soil moisture and texture.

It appears from an account by Newhall (1946) on fumigation practice that the approximate nematocidal dosages to be injected to 10-inch centres per 100 square inches amount under favourable conditions to : 0.6 c.c. of methyl bromide, 1 c.c. of ethylene dibromide, 2 c.c. of chloropicrin, 4 c.c. of DD, 6 c.c. of carbon disulphide, 6 c.c. of Dowfume G (methyl bromide in 3 to 1 mixture with ethylene dichloride and carbon tetrachloride), and 10 c.c. of ethylene dichloride. Taylor (1949) gives application rates per acre, viz.: 200–400 lb. of chloropicrin, 500 lb. of Dowfume G, 500–1,000 lb. of carbon disulphide, or 4,000 lb. of ethylene dichloride. Organic soils, however, require

substantially higher rates (Taylor, 1951) and adjustments are necessary in soils of high clay or moisture content, particularly at low temperatures.

Several investigators (Bickerton, 1948 ; Leavitt, 1948 ; Thorne, 1948) indicated that greatest efficiency from this type of chemical may be expected in well tilled soils of about 10–20 per cent. moisture and 70° F. temperature. Injected 5–8 inches deep, penetration and dissipation will be sufficiently rapid to do a quick job and to make planting 8–10 days after treatment possible.

As a fungicide, formaldehyde was found to be more efficient than inorganic compounds (Doran *et al.*, 1942) and to be less susceptible to fixation by soil (Milbrath, 1931). The persistence of formaldehyde, and to a lesser extent of paraformaldehyde, in phytotoxic concentrations was, however, comparatively long ; a delay of 10–20 days was required after treatment with 1 per cent. solution (Staehlin, 1945), and up to 4 weeks with slightly stronger solutions (Jacks, 1949), before planting could be undertaken with safety.

Effects on Soil Fertility

The effects of partial sterilization, especially by steam, on soil have already been reviewed in *Soils and Fert.* XI, pp. 357–360. Soil antiseptics as a whole have a favourable influence on fertility, but may also induce chemical changes that ultimately become harmful to plants.

Jacks (1945) found that both chloropicrin and DD increased tomato yields even in soils free of pathogenic organisms. This may primarily be due to their favourable effect on organisms participating in the nitrogen cycle (Pochon and Lajudie, 1948). Nitrification was temporarily depressed for about three months after treatment with volatile fumigants (Cawthron Institute, 1948). Chloropicrin increased readily available nitrogen and delayed nitrification longer than did steam sterilization (Kidson, 1948), and DD appeared milder in its effects, thus making it preferable before crops which do better with a nitrate type of nutrition (Tam, 1945). The increased growth of pineapple following chloropicrin treatment was, on the other hand, related to the predominantly ammonia nutrition of the plants (Tam and Clark, 1943). The accumulation of ammonia in acidic soils or its appreciable loss in alkaline soils might, nevertheless, unfavourably affect plant growth (Smith, 1939).

Aldrich and Martin (1952) found that the proportions rather than the total amounts of ammonia and nitrate nitrogen were affected by volatile antiseptics. The biological and chemical changes brought about by fumigation largely depended on the soil and on the agent used. Propylene oxide and ethylene dibromide affected nitrifying organisms least, and nitrification following treatment began sooner in sandy alkaline than in acid mountain soil. Treatments caused an initial increase of soluble calcium, magnesium, and potassium and there was also, particularly with carbon disulphide, a release of soil manganese mainly from inorganic sources. The anion

composition of soils was little affected by treatments, except when the fumigants contained chlorine or sulphur which were released upon decomposition in the soil.

Another investigation by the same authors (Martin and Aldrich, 1952) showed that the application of fumigants, in contrast to steam sterilization, did not cause any significant increase in soil aggregation. Most of the organisms developing after fumigation were bacteria in alkaline soils and fungi in acid soils. Numbers of organisms in treated soils were up to 14 times those in untreated soils. The greatly increased microbial activity appeared to accelerate the destruction of organic aggregating substances, and to result in a decrease of aggregation.

Sherman and Fujimoto (1947) showed that DD did not affect soil manganese directly. It increased the exchangeable iron in soil and thus reduced the manganese-iron ratios in the plants. Chloropicrin, however, apparently increased the solubility of soil manganese, as shown by the consistently higher manganese-iron ratios produced by this chemical compared with DD.

Studies on the effects of volatile chemicals on soil manganese were undertaken by Dalton and Hurwitz (1948). Complete sterilization of soils in sealed containers by chloropicrin or formaldehyde occurred in 8 days and 3 days respectively and increased the ammonium-acetate-soluble manganese and copper to toxic levels. Ethylene oxide, which sterilized soils after exposure for 11 hours, caused insignificant changes in the solubility of these elements.

Exposure for 16 hours to 0.8 atm. of ethylene oxide, however, caused considerable changes in some soil properties (Clark, 1950). It increased the total carbon in a silt loam from 2.84 to 3.88 per cent. and the readily available phosphorus from 9.3 to 12.7 p.p.m., and raised pH values from 6.30 to 7.76. There was evidence that the added carbonaceous material was readily utilized by micro-organisms, and investigations by Allison (1951) confirmed that the volatile compound was by some catalytic action of the soil colloids transformed into ethylene glycol.

REFERENCES

Aldrich, D. G. and Martin, J. P. 1952. *Soil Sci.* **73**, 149–159.
Allen, M. W. and Raski, D. J. 1950. *Phytopath.* **40**, 1043–1053.
Allison, L. E. 1951 *Soil Sci.* **72**, 341–352.
Bickerton, J. M. 1948. *Proc. Fla. St. Hort. Soc.* 1947. **60**, 114–116.
Cawthron Institute. 1948. *Cawthron Inst. Rept.* 1947–48, 13–14.
Chisholm, R. D. and Koblitsky, L. 1943. *J. Econ. Ent.* **36**, 549–551.
Clark, F. E. 1950. *Soil Sci.* **70**, 345–349.
Dalton, F. H. and Hurwitz, C. 1948. *Soil Sci.* **66**, 233–238.
Doran, W. L., Guba, E. F. and Gilgut, C. J. 1942. *Mass. Agric. Expt. Sta. Bull.* 394, pp. 20.
Fuhr, I., Bransford, A. V. and Silver, S. D. 1948. *Science* **107**, 274–275.
Hagan, R. M. 1941. *Hilgardia* **14**, 83–118.
Hannesson, H. A. 1945. *Hilgardia* **16**, 501–510.
Jacks, H. 1945. *N.Z. J. Sci. Tech.* **27**A, 250–255.
Jacks, H. 1948. *N.Z. J. Sci. Tech.* **30**A, 115–123.
Kidson, E. B. 1948. *N.Z. J. Sci. Tech.* **30**A, 193–199.
Lear, B. 1951. *Cornell Agric. Expt. Sta. Mem.* 303, pp. 48.
Leavitt, F. H. 1948. *Proc. Amer. Soc. Sug. Beet Technol.* **5**, 509–513.
Lubatti, O. F. and Smith, B. 1948. *J. Soc. Chem. Indust.* **67**, 347–354.

McClellan, W. D., Christie, J. R. and Horn, N. L. 1949, *Phytopath.* **39**, 272–283.
Martin, J. P. and Aldrich, D. G. 1952. *Proc. Soil Sci. Soc. Amer.* **16**, 201–203.
Milbrath, D. G. 1931. *California D/A Monthly Bull.* Vol. **20**, 673–681.
Newhall, A. G. 1946. *Soil Sci.* **61**, 67–82.
Pochon, J. and Lajudie, J. 1948. *C. R.* **226**, 2091–2092.
Richardson, H. H., Johnson, A. C. and Bulger, J. W. *et al.* 1943. *U.S.D.A. Tech. Bull.* 853, pp. 20.
Shchepetilnikova, A. and Cheremisova, V. 1937. *Khim. Sotsial. Zemled.* 8, 39–52.
Schmidt, C. T. 1947. *J. Econ. Ent.* **40**, 829–837.
Sherman, G. D. and Fujimoto, C. K. 1947. *Proc. Soil Sci. Soc. Amer.* 1946, **11**, 206–210.
Siegel, J. J., Erickson, A. E. and Turk, L. M. 1951. *Soil Sci.* **72**, 333–340.
Smith, N. R. 1939. *Proc. Soil Sci. Soc. Amer.* 1938, 3, 188.
Staehelin, M. 1946. *Sta. Fed. Vitic. Arboric. Chim. Agric. Lausanne Rapp.* 1945, 767–768.
Stark, F. L., Jr. 1948. *Cornell Agric. Expt. Sta. Mem.* 278, pp 61.
Stark, F. L., Jr. and Lear, B. 1947. *Phytopath.* **37**, 698–711.
Tam, R. K. 1945. *Soil Sci.* **59**, 191–205.
Tam, R. K. and Clark, H. E. 1943. *Soil Sci.* **56**, 245–261.
Taylor, A. L. 1949. *Proc. Soil Sci. Soc. Fla.* IV-B, 1942, 126–140.
Taylor, A. L. 1951. *Adv. Agron.* **3**, 243–264.
Thorne, G. 1948. *Canner.* **106**, No. 14, 12–13.
Wilson, J. D. 1943. *Ohio Agric. Expt. Sta. Bimo. Bull.* **28**, 38–41.

JUTE SUBSTITUTE FIBRES

By A. E. HAARER. *Wheatland Journals Ltd., London,* 1952. *Pp.* xxi+185. *Illustrated. Price* 30/-.

The subject of fibre production has been one of increasing importance during recent years and this book has appeared at an opportune time for both research workers and planters as a book of reference.

The author has obviously taken great pains to examine existing literature relative to jute substitute fibres and has produced a book in which existing information on the subject has been carefully collated and presented in a very readable form. The book is well illustrated by photographs, coloured plates and line drawings. The subject matter has been well arranged for easy reference and the bibliography at the end of the book provides a valuable list of references.—W.J.B.

CONTRIBUTION TO THE KNOWLEDGE OF THE YEAST FLORA OF FERMENTING CACAO. [1. A CRITICAL REVIEW OF THE YEAST SPECIES PREVIOUSLY DESCRIBED FROM CACAO.]

By

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Introduction

Although it has been recognised for more than half a century that the first stage of the fermentation of the seed-pulp of cacao is an alcohol producing dissimilation process induced by yeasts, these organisms have not been satisfactorily studied. Since it is likely that these yeasts contribute characteristically to the full flavour of the cocoa, and evidence exists that the rate of predominance of certain species is influenced by dissimilarities in the conditions under which the cacao beans are fermented in different parts of the world, a thorough investigation of local variations in the composition of this microflora is certainly justified. The present study may contribute to the knowledge of the ever important subject of cacao fermentation.

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The smell of alcohol given off by freshly fermenting cacao beans soon after they have been heaped up is very striking. It is, therefore, not surprising that it was early assumed that alcohol was produced by a yeast fermentation of the sugars in the seed pulp. The first descriptions of the species involved in this fermentation process are certainly not reliable, since in those years the taxonomy of the yeasts was still in its infancy.

Chittenden (1890) was the first investigator who ventured a denomination of a cacao yeast when he suggested that *Saccharomyces cerevisiae* was an important species in Trinidad. Since Chittenden found it necessary to use a question mark to the name it is obvious that his suggestion cannot possibly have been more than a mere guess.

The same qualification applies certainly to Preyer's work (1901). He described a new Saccharomyces by the name *S. theobromae* as being the typical yeast of fermenting cacao in Ceylon. This species was, according to Preyer, distinct from all previously described yeasts, but should nevertheless resemble Hansen's *S. membranaefaciens* and *S. ellipsoideus I*. This shows clearly that such a resemblance must have been purely morphological since the two latter species differ in many physiological properties : *S. membranaefaciens* had been described by Hansen as a non-fermenting species, whereas *S. ellipsoideus* was known to ferment glucose, sucrose, and maltose vigorously. Preyer stated that his *S. theobromae* did not ferment sucrose but fermented the glucose in the cacao pulp. The morphological description which accompanies Preyer's drawings is a further demonstration of his poor knowledge of the yeasts ; assimilation products inside the cells are described as ascospores of which one finds up to 24 drawn in one single ascus : " The spores are very small and fill up the cells in great numbers ". Apart from all this Preyer apparently did not describe his species from a pure culture.

The name *S. theobromae* was, however, fascinating enough to make it persist throughout the literature on cacao fermentation, though Ciferri (1931) transferred the species to the genus Eutorulopsis. Even Knapp (1937) in his excellent book on cacao fermentation still reproduces Preyer's drawings as a source of information.

In 1907 Loew mentioned from Porto Rico particularly *S. ellipsoideus*, and as a less common species *S. apiculatus*. He did not give any description of these yeasts nor of the way in which he identified them. Smith (1913) confirmed that he had discerned in Porto Rico only these two species " in a lot of fermenting cacao beans " without giving any ground for his confirmation.

Bainbridge and Davies (1912) explained the biochemical nature of the cacao fermentation in Jamaica as follows : " In the first stage there is a large growth of *S. apiculatus* (" Yeast ") together with small quantities of *S. anomalus*, &c., doubtless derived from the surface of the pod husks. After this stage, which lasts about 12 hours, an enormous development of true,

oval and round-celled Saccharomyces occurs, as in spontaneous wine fermentation. " No description is given from which the reliability of this classification is apparent. The authors continue : " The alcohol produced soon arrests the growth of *S. apiculatus* and the wild yeasts." From this it is obvious that *S. anomalus* was correctly recognized as a " true " Saccharomyces, whereas *S. apiculatus* (nowadays classified as *Kloeckeria apiculata*) was distinct by some properties of a " wild yeast ".

Nicholls (1913) was the first investigator who described in full how he isolated his yeasts from fermenting cacao in St. Lucia on potato-glucose agar enriched with minerals. His method is, however, not a guarantee that he always dealt with pure cultures, since he simply picked the different colonies from dilution plates without checking their homogeneity. Unfortunately Nicholls did not give a description of any of his yeast strains. He stated only that the organisms of the yeast stage are " wild " yeasts, which means that " if we compare this yeast with baker's it will be found that they differ from one another in shape, size, and general appearance ". He continues : " There are a number of varieties of yeasts, and many can be found in sweating cacao taken from different situations. But, as found in association with cacao, since they are usually of a very definite type, an attempt has been made to regard them, irrespective of minor differences, as one species and to apply the name *S. theobromae* to these ". It is obvious that Nicholls was not aware of Preyer's publication and denomination of *S. theobromae* six years earlier. There can be no doubt that Nicholls used the same name this time for a whole population of different yeasts. Since he did not give descriptions or detailed drawings his classification is at the most of historical interest.

Of greater importance is the work of Von Lilienfeld-Toal (1927). Unfortunately this investigator examined exclusively dried, fermented beans. His assumption that yeasts which are only occasionally met with on commercial samples are of no importance for the fermentation process is even more debatable than his claim that those which are regularly present on dried beans are characteristic for the microflora of sweating beans. The following yeasts are described by Von Lilienfeld-Toal as being isolated from all samples originating from Costa Rica, Ecuador, Venezuela, Trinidad, Brazil, Gold Coast, San Thome, Ceylon, and Java.

Saccharomyces ellipsoideus var. tropicus. ("Kakao Wein Hefe ") ; the creation of this new variation was only based on the observation that its optimum temperature was 37°–40°C., and its maximum temperature 42°–45°C., both being higher than found for Hansen's species.

Schizosaccharomyces Bussei, which is described as a new " species or race ". However, no evidence is given that this yeast is sufficiently different from *S. Pombe* to justify its separation as a distinct and new species. In contrast to *S. Pombe* Von Lilienfeld-Toal's isolation shows hardly any surface growth on broth, and its colonies on agar are paler. These minor differences

must be considered as remaining within the limits of variation of the species *S. Pombe*, so that the maintenance of the species *S. Bussei* cannot be justified.

Saccharomyces anomalus, already mentioned from earlier investigations.

"*Kahmhefe A*". This is an anascosporogenous, scum-forming yeast, producing alcohol from glucose only. This description is not sufficient to make a further identification possible. Ciferri (1931) stated that this species is identical with his *Eutorulopsis theobromae.*

Apart from these four species Von Lilienfeld-Toal described four other yeasts which are not classified. They are not worth a discusssion here since they were all isolated once only from a commercial sample in Europe, and nothing indicates further that they might have had anything to do with cacao fermentation.

Steinmann (1927) followed in the footsteps of the previous investigators. He isolated in Java amongst the early "mould yeasts" after 12 hours of fermentation, "an *apiculatus* yeast" the cells "having the typical apiculatus shape". From later stages of the fermentation he isolated "a true wine yeast of the type of *S. ellipsoideus*", and an unclassified "yeast with longish cells" with four spores per ascus. After cognizance of the work of Von Lilienfeld-Toal (1927) and having compared the description of cacao yeasts given by that author with his own observations, Steinmann (1928) classified his unidentified yeast as *Schizosaccharomyces Bussei*, and pointed out the identity of his "wine yeast" with *Saccharomyces ellipsoideus var. tropicus.* Moreover he considered his "mould yeast" to be the same as Von Lilienfeld-Toal's "Kahmhefe A". It is of interest that he stressed the absence of *S. anomalus* in Java.

Ciferri (1931) stated that he found in the Dominican Republic the following species of yeasts in fermenting cacao : *Saccharomyces ellipsoideus var. tropicus*, always present in abundance. The rather good description makes it very likely that this yeast would be better classified now as *S. oviformis* because of its ability to ferment glucose, fructose, sucrose, maltose, and raffinose, but not galactose. Ciferri's claim that its fermentation of mannose was found to be negative should not be taken too seriously (see under *Kloeckeria cacaoicola*). *S. Bayanus* which has similar fermentative properties to *S. oviformis* has to be excluded because of Ciferri's statement that his *S. ellipsoideus var. tropicus* has normally spheric vegetative cells, and that sub-elliptic cells were only found in the deposit in liquid media. The cells measured (2.5–5) $\mu \times$ (3–7) μ.

S. ellipsoideus var. domingensis, nov. var. Almost as frequently met with as the previous type. Ciferri stated that this Saccharomyces fermented glucose and galactose but not sucrose, maltose, and raffinose. Therefore this species, which is described as bearing 1–4 spores per ascus and forming no chains in broth, is now better classified as *S. globosus* Osterwalder.

Endomyces anomalus (Saccharomyces anomalus), exceedingly frequent.

Schizosaccharomyces Bussei. Ciferri stated that "this species is of the cycle of *S. Pombe*", but he failed to indicate in what respect it differs from the latter, except for the lighter shade of its colonies on agar. This could certainly not justify its maintenance as a distinct species.

Kloeckeria cacaoicola, nov. spec. This species is said to invert sucrose ; however it does not ferment this sugar, although glucose is readily fermented. Ciferri's claim that fructose was not fermented would open interesting fields if it could only be proved that it was based upon correct observations. This correctness is, however, extremely unlikely. Since Kluyver (1914) found the rule that all yeasts which ferment glucose are capable of fermenting fructose and mannose as well, no other observation has ever been made which is not in harmony with its general validity. Ciferri's description of the dissimilative properties of his new species needs confirmation to justify its existence.

Kloeckeria domingensis, nov. spec. This species was only " very rarely found on fermenting cacao beans ". It was described by Ciferri (1930) as differing from *K. magna* De Rossi by its larger cells, and by its production of more acid from glucose, and by not being capable of fermenting sucrose. Ciferri's new species had cells measuring (4–8) $\mu \times$ (6–12) μ. De Rossi (1920) quoted for the size of *K. magna* (2.7–4.8) $\mu \times$ (4.8–9.6) μ, whereas Lodder (1934) found for the C.B.S. strain originating from De Rossi's collection (3.5–6) $\mu \times$ (5.5–10) μ. Ciferri's claim that his *K. domingensis* was different from *K. magna* because the former did not ferment sucrose is without adequate grounds. De Rossi mentioned only that *K. magna* ferments the juice of grapes, and Lodder ascertained that the C.B.S. strain does not ferment sucrose. It seems therefore that *K. domingensis* was not essentially different from *K. magna*. Neither the occasional occurrence of larger cells nor the greater acid production as observed by Ciferri can justify the maintenance of *K. domingensis* as a distinct species.

Eutorulopsis theobromae (*Saccharomyces theobromae*, Preyer). The transfer of this species from the genus Saccharomyces into the genus Eutorulopsis was certainly a taxonomic improvement ; it is an anascosporogenous yeast, forming a scum on liquid media, and producing alcohol only from glucose. Ciferri is of the opinion that this species was identical with Von Lilienfeld-Toal's " Kahmhefe A".

Torulopsis Lilienfeld-Toalii, nov. spec. Ciferri stated that in liquid media this very common species formed blastospores in great numbers. Therefore this species can no longer be accepted as a Torulopsis and must be classified as a member of the sub-family Mycotoruloideae. Judged by the description given by Ciferri it is obviously a *Candida* species, but a further classification is too speculative.

Torulopsis Hamel-Smithii, nov. spec. " Probably of accidental presence in fermenting cacao ". Classifying it from the description it is certainly a Torulopsis, but the species cannot be identified.

Schizoblastosporion domingensis, nov. spec. This species cannot be maintained as distinct from *S. Starkeyi-Henricii* previously described by Ciferri (1930). The main justification for such a separation would lie not so much in the slight differences in cell shape and size, as in Ciferri's statement that the former assimilates both glucose and fructose, whereas the latter should assimilate exclusively glucose. This statement of Ciferri is, however, not correct. Lodder (1934), working with the same strain of *S. Starkeyi-Henricii* from which Ciferri's original description was made, found that it assimilates both glucose and fructose, as could be expected.

Torulopsis aurantiaca. " Probably accidently present on fermenting cacao ".

Torulopsis mucilaginosa. Isolated only once, and " must be considered as an accidental contamination of the fermenting cacao beans ".

Mycotorula ramosa var. dominicana, nov. var. From the description given by Ciferri its systematic position cannot easily be made clear. The statement that the cells contain a yellow to reddish pigment and form a root-like mycelium reveals such an unusual combination of properties that the maintenance of this species is not justified without further examination.

Several species of *Geotrichum*. By the description given by Ciferri it is evident that, because of the mycelium with blastospores and arthrospores, at least some of these species belong to the genus *Trichosporon*.

According to Knapp (1937) Dade isolated several yeasts from fermenting cacao in the Gold Coast, some of which were sent for classification to the Yeast Division of the Centraal Bureau voor Schimmelcultures at Delft (Holland). Four of these should have been described as new species, three belonging to the genera *Hansenula*, *Kloeckeria*, and *Mycoderma*, and the other belonging to the group of the Mycotoruloideae. This statement of Knapp is apparently not correct. The only reference made to not more than two of Dade's strains is in the monography on the anascosporogenous yeasts of the Delft collection by Diddens and Lodder (1942). They are called " Gold-Coast yeast b " and " Cacao yeast d ", which are classified as *Candida Krusei* and *C. Krusei var. vanlaeriana*, respectively. This year the author obtained privately the following information from the C.B.S. at Delft. In 1932 the five strains isolated by Dade were temporarily classified as :

yeast " a " : *Kloeckeria* spec.
yeast " b " : a species belonging to the *Mycotoruloides*.
yeast " c " : *Hansenula* spec.
yeast " d " : *Mycoderma* spec.
yeast " f " : *Saccharomyces cerevisiae*.

The yeasts " b " and " d " were then in 1942 classified by Diddens and Lodder as *Candida Krusei* and *C. Krusei var. vanlaeriana*, respectively. In

the new monograph on the C.B.S. yeasts, which is not yet published, the definite classification will be as follows :

yeast " a " : *Kloeckeria apiculata*

yeast " b " : *Candida Krusei*

yeast " c " : *Pichia fermentans*

yeast " d " : *Candida mycoderma* (Rees) nov. comb, (formerly *C. Krusei var. vanlaeriana.*)

yeast " f " : *Saccharomyces cerevisiae.*

In their comprehensive study on cacao fermentation in Java, Roelofsen and Giesberger (1947) mention by names, only two yeast strains out of the many which were studied. These are a *Pichia* spec. and a *Saccharomyces* spec. which were not further determined.

Summary and Discussion

The literature on cacao yeasts is critically reviewed. It is difficult and sometimes even impossible to identify the various species of yeasts reported by some investigators. Most descriptions are very incomplete and often observations were not made with the aid of the necessary technique of growing isolated strains in pure cultures. As far as possible, however, all species ever reported from fermenting cacao are determined in accordance with the classification now generally accepted. The following list of species of which the identification seems to be reasonably certain can be set up from the investigations hitherto published.

Species	Isolated from	or Reported by
Saccharomyces cerevisiae Hansen	Gold Coast	Dade
S. cerevisiae var. *ellipsoideus* (Hansen) Dekker	Ubique	
S. globosus Osterwalder (?)	Dominican Republic	Ciferri
S. oviformis Osterwalder (?)	Dominican Republic	Ciferri
Schizosaccharomyces Pombe Lindner ...	Ubique	
Pichia fermentans Lodder	Gold Coast, Java (?)	Dade Roelofsen & Giesberger
Hansenula anomala (Hansen) Sydow ...	Ubique	
Rhodotorula aurantiaca (Saito) Lodder ...	Dominican Republic	Ciferri
Rh. mucilaginosa (Jorgensen) Harrison ...	Dominican Republic	Ciferri
Torulopsis (*Eutorulopsis*) sp. (" *Saccharomyces theobromae* ") ...	Ubique	
Kloeckeria apiculata (Rees) Janke ...	Ubique	
Schizoblastosporion Starkeyi-Henricii Ciferri	Dominican Republic	Ciferri
Candida Krusei (*A. Cast.*) Berkhout ...	Gold Coast	Dade
	Dominican Republic	Ciferri
C. Krusei var. *vanlaeriana* (Lindner et Gen.) Diddens et Lodder ...	Gold Coast	Dade
Trichosporon sp.	Dominican Republic	Ciferri

The species *Kloeckeria cacaoicola*, *Torulopsis Hamel-Smithii*, and *Mycotorula ramosa*, reported by Ciferri from the Dominican Republic, cannot be taken into consideration as long as they are not available for checking their classification.

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REFERENCES

1. Bainbridge, J. S., and Davies, S. H. (1912). *Transact. Chem. Soc.* II, **101**, 2209.
2. Chittenden (1890). *Agric. Record*, **2**, 107.
3. Ciferri, R. (1930). *Arch. f. Protistenkunde*, **71**, 405.
4. ——————(1931). *J. Dept. Agric., Porto Rico*, **15**, 223.
5. Diddens, H., and Lodder, J. (1942). "Die anaskosporogenen Hefe II". Amsterdam. pp. 192–194.
6. Kluyver, A. J. (1914). "Biochemische Suikerbepalingen". Thesis Delft, p. 22.
7. Knapp, A. W. (1937). "Cacao Fermentation", London, p. 26.
8. Lilienfeld–Toal, O. A. von (1927). *Beih. z. Tropenpflanzer* 30, No. 2.
9. Lodder, J. (1934). "Die anaskosporogenen Hefe I". Thesis, Utrecht, p. 238.
10. Loew, O. (1907). *Ann. Rep. Porto Rico Agric. Station*
11. Nicholls, L. (1913) in H. H. Smith's "The Fermentation of Cacao", London, p. 221
12. Preyer, A. (1901). *Tropenpflanzer*, **5**, 157.
13. Roelofsen, P. A. and Giesberger, G. (1947). *Archief Koffiecultuur*, **16**, 1.
14. Rossi, G. de (1920). *Stazioni Sperimentali Agric. Italiane*, **53**, 233.
15. Smith, H. Hamel (1913). "The Fermentation of Cacao", London, p. 276.
16. Steinmann, A. (1927). *Archief v. d. Cacao*, **1**, 5.
17. ——————(1928). *Archief. v. d. Cacao*, **3**, 71.

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THE EFFECT OF ELEVATION ON GROWTH, CARBOHYDRATES AND INSECTICIDAL CONSTITUENTS OF DERRIS AND LONCHOCARPUS[1]

By

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Two varieties of *Derris elliptica*, Sarawak Creeping and MG-clone 8 and one variety of *Lonchocarpus* sp. were grown in Puerto Rico for two years at four elevations ranging from 80 to 3,300 feet above sea level.

The Sarawak Creeping variety was adapted to the widest range of altitudes, although it grew best at elevations ranging from 1,200 to 2,400 feet. *Lonchocarpus* sp. was the most exacting in its environmental requirements, the best growth being made at 1,200 feet elevation but even there the growth was only fair compared to the other two varieties. MG-clone 8 made fair to excellent growth in the altitude range of 80 to 2,400 feet. However, the best growth was made at 1,200 feet and little or no growth was made at 3,300 feet.

The percentage of insecticidal constituents in the roots of all varieties decreased consistently as altitude increased but the percentage of total carbohydrates in the roots increased with altitude.

The MG-clone 8 had the highest percentage of insecticidal constituents at all locations. The percentage T.C.E.[2] of this variety varied from 18.2 at the lowest elevation to 7.6 at 2,400 feet. The T.C.E. values of the Sarawak Creeping varied from 11.0 to 1.0 per cent. and for the *Lonchocarpus* sp. the values ranged from 15.3 to 3.4 per cent.

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[1] This paper will be published in full in Vol. 2, No. 4, of Turrialba.

[2] Total chloroform extractives.

COMMUNICATIONS ON ORIGINAL INVESTIGATIONS

RED RING DISEASE OF COCONUTS IN TRINIDAD AND TOBAGO

BY

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Summary

A short account is given of the origin of red ring disease of coconuts in Trinidad, its distribution elsewhere, and early investigations of the disease. Reference is made to serious losses caused in recent years. The symptoms of the disease are described and shown to be associated with the production of a strongly reducing substance in the periphery of the cortex of young palms invaded by the nematode *Aphelenchoides cocophilus.*

Experiments on the inoculation of stems and roots are described. These showed penetration via the leaf axils to be the normal means of entry of the parasite, root infections, though successfully carried out artificially, being of no account under natural conditions. The coconut weevil, *Rhynchophorus palmarum*, and by inference *Rhina barbirostris*, also was shown to be able to transmit the disease by burrowing in diseased débris in the cortex of affected palms, emerging with legs and body covered with this débris, and transferring it to wounds or to leaf axils in adjacent palms.

Reference is made to reports of natural and artificial alternative hosts of the parasite, and it is concluded that under natural conditions the disease is confined to the coconut palm, at least in the Lesser Antilles.

Control of the disease is shown to be possible by the removal of all infected palms and complete destruction of diseased tissues by fire.

Introduction

Red ring disease of coconuts, due to the colonisation of the periphery of the cortex of young palms by the nematode *Aphelenchoides cocophilus* (Cobb), is an endemic disease of South and Central America. It is known in Brazil, Venezuela, Colombia, Panama, and British Honduras, but its once reported presence in British Guiana is incorrect. The disease has also, in course of time, found its way from the mainland to Trinidad, Tobago, Grenada, and St. Vincent in the Lesser Antilles.

Red ring was known in Trinidad and Tobago fifty years ago as 'root disease', under which name it was studied by several mycologists, until in

1918 Nowell, investigating the disease in Grenada, realised the significance of the eelworms found so plentifully in the affected tissues, and showed them to be the cause of it. The nematode concerned was examined and named by Cobb (1919), and further experimental work by Nowell and Ashby (1919–1924) threw more light on the aetiology of the disease. Though failing to discover its means of spread, they stressed the importance of complete and effective destruction of affected palms by fire, and also suggested trenching to contain the nematodes ; there the matter remained for some thirty years.

Apparently, when the Trinidad coconut industry was expanding in the second and third decades of the present century, the disease did not cause excessive damage in the new plantations, doubtless because it was absent in most of the newly planted areas to begin with, and did not have time to build up a large source of potential infection before the plants passed the most susceptible age—four to seven years old. The subsequent supplying of these plantations was generally carried out haphazardly, either by casual planting in gaps that arose, or by leaving these to be filled by ' drop nuts ' conveniently germinating near the right place. The result was that the older plantations always contained a number of young palms of varying age, scattered, and not all at the age of greatest susceptibility. Losses from the disease were sometimes quite extensive, but on the whole the deaths did not seriously affect output and were accepted as inevitable. In some cases planters took phytosanitary measures to check the rate of spread.

In recent years, however, coconut planters on the East coast of Trinidad, after felling the original palms, have started replanting whole fields with seedlings, raised in nurseries from selected nuts. In such plantings, all the young palms in a field reach the age of maximum susceptibility at the same time, and the disease has been causing such serious losses (in some cases over 60 per cent. by the fourth or fifth year) that rehabilitation of the plantations in this manner seemed impossible to achieve. Consequently the planters concerned asked for further investigation of the disease, and this was carried out at Nariva-Cocal, where heavy loss had been sustained.

Description of the Disease

The appearance of the disease was well described by Nowell (1923), his account being quoted in most subsequent references. The initial yellowing and subsequent drying out and browning of the leaves can, however, occur in palms affected by other adverse factors. The leaf colour changes generally start with the oldest leaves, the occasions when younger leaves are first affected being due no doubt to primary infection higher up the stem. The age and size of palms attacked varies somewhat in different accounts of the disease ; but, in general, coconuts are most susceptible from the time they first form a clearly defined stem with a cortex of soft tissue till the time when this cortical tissue hardens. This period, of course, varies with the conditions under which the palms grow, but in Trinidad is generally from the fourth to the seventh year. In Brazil the disease is recorded on palms up to ten years of age (Jofilly, 1948).

Artificial infection of the stem resulted, as a rule, in the appearance of external symptoms about six weeks later, though occasionally, they appeared before and sometimes were delayed for eight weeks or so. The rate of growth of the palm and prevailing weather conditions are relevant factors in the rapidity with which the symptoms develop.

The red ring forms about two inches from the periphery of the stem, starting as a faint but quite distinguishable line around it, and soon developing into a band some one to one and a half inches in width, often red-brown to brown rather than red in colour. The nematodes are massed in this area, to which they are almost entirely confined, and where they apparently encounter optimum conditions. Aeration and water supply are probably the determining factors that account for their absence nearer the centre of the stem, and the harder tissues confine them on the outside, so defining the limits of the ring. After the cortical tissues harden they are apparently not favourable for the existence of the nematodes, which no doubt accounts for the general absence of the disease in older palms. In addition to the red ring area of the trunk, nematodes may be found generally distributed in the ground tissues of infected petioles.

The discolouration of the tissues is associated with the presence of a high nematode population, and in the orange-brown zone strongly reducing conditions are found. The destruction of this zone of tissue is apparently the direct cause of the external leaf symptoms and subsequent death of the palms, which may be due to the toxic substances formed, but the actual mechanism of the destructive process is obscure.* Leaf symptoms probably depend to some extent on whether direct infection of the petiole or secondary infection from the stem occurs. Growth of the palm sometimes continues for a week or so after external leaf symptoms are evident, or may cease rather sooner.

*The writer is indebted to Mr. K. W. de Witt of the Imperial College of Tropical Agriculture for kindly investigating this matter. He reported as follows :—

"In the course of a chemical examination of the tissues of Coconut palms affected by red ring disease it was observed that in an advanced state of the disease the red ring area of the cortex exhibited highly reducing properties towards ammoniacal silver nitrate solution. A drop of the reagent applied to the red ring was blackened within 10–15 seconds, whereas in all other parts of the cross section of the trunk several minutes elapsed before darkening was noted. In healthy palms, and in those in very early stages of the disease, no such effect was obtained.

The reducing material present in the reddened tissue was water soluble, and was estimated by titration against 2–6–dichlorphenol indophenol (Harris & Olliver, Biochem J. **36**, 155, 1942). Results, expressed as ascorbic acid, are given in the following table :—

Distance from periphery of trunk (c.m.)	0–4	4–6.5 (red ring area)	7–30
Reducing material (mg. ascorbic acid/ 100 gm tissue)	3.2	63.0	1.2

Thus the reducing power of the tissue in the red ring is 20–60 times greater than in other parts of the trunk."

The red ring is the surest symptom of the presence of the disease. A brace and ½ inch bit, the latter penetrating to a depth of three inches, withdraws tissue in which the typical discolouration can be noted and the disease recognised, two or three weeks before external symptoms appear, and without the necessity of felling the palm. Such borings are readily repaired with a wooden plug and a covering of plasticine, to prevent the attraction of weevils.

Stem Inoculation Experiments

(*a*) *Very young plants*

Attempts were made to infect young palms (about two years old) in which the leaves were just becoming pinnate, growing in tubs. As in subsequent experiments, pieces of red ring tissue were placed in water in a funnel, and allowed to stand for a while, after which the water, containing large numbers of nematodes, was drawn off from the stem of the funnel for use as inoculum, either as it was, or after dilution. Water containing nematodes was poured over the plants, the petioles of which had in some cases been nicked with a scalpel. In other experiments, with similar palms, pieces of red ring tissue were inserted in wounds in the petioles, or placed in the leaf axils. In no instance was infection obtained. (Ashby (1921 *b*) claimed to have once artificially infected an eleven-month-old palm in the field, though failing with similar plants in pots.)

(*b*) *Older palms.*

Inoculation of older palms was carried out in the field, in areas where the disease had not yet appeared, so that natural infection was unlikely to occur. Palms of about four years old were successfully inoculated by repeating Nowell's methods, i.e. placing pieces of diseased tissue in wounds in stems and petioles, or in unwounded leaf axils. In these cases, however, there was the possibility that some fungal or bacterial organism in the diseased tissue, and not the nematodes, might have caused the infection. Other palms were therefore inoculated simply by introducing the nematodes in water to the leaf bases with a pipette. Nine palms were inoculated in this manner, and infection was obtained in every case, in some instances during the dry season. It is not only apparent, therefore, that the nematode alone causes the disease, but that it can readily gain entry via the leaf bases, as Nowell believed, and this, as will be shown, is no doubt the normal way of infection.

An attempt to inoculate a palm of some 20 years of age by boring holes in the trunk and inserting pieces of red ring tissue—a certain means of infecting younger palms—failed to cause infection.

Attempts were made to establish the eelworms in portions of trunk about two feet long, cut from the stem of a young, healthy palm and trimmed of leaf bases. These were brought to the laboratory, stood upright in trays of water, and the cut surface at the top kept covered with moist filter paper. These pieces were kept thus for 10 days, the cortical tissues remaining apparently fresh throughout this period. A number of borings were made with brace and bit, into which were introduced nematodes in water, or pieces

of red ring tissue, and the holes were then plugged. In no case did the nematodes establish themselves in the cortical tissues, and it seems evident, therefore, that for their well-being and multiplication the natural movement of solutes in the tissues of the living plant is necessary. The removal of staling products is no doubt essential.

Root Inoculation Experiments

Examination of roots of diseased palms showed nematodes to be present in the cortex of older hard, brown anchoring roots that emerge directly from the base of the trunk; but they were not found in the younger, lighter coloured feeding roots, nor in washings from soil taken from around diseased palms.

As in other cases, when the presence of eelworms was looked for in soil or tissues, the material was allowed to stand in water in a funnel, if need be overnight, a sample of the water being then run off and examined for nematodes.

(*a*) *Very young palms.*

Attempts were made to inoculate the roots of three two-year-old palms just forming pinnate leaves, and growing in tubs, by burying pieces of diseased tissue among the roots. One palm was dug up after a week, another after two weeks and the third, still apparently healthy, after a lapse of five months. The roots were washed and examined, but in no case were eelworms found in them.

In another experiment, six germinated dwarf coconut seedlings with shoots three to four feet high and roots about one foot in length were stood in glass jars in the laboratory, the roots being submerged. The roots of three of these were damaged by cutting off portions, particularly of the larger ones, with scissors. Water containing nematodes was then added, and in addition pieces of infected tissue were placed in the jars, so that they floated among the roots. After a week the roots were examined, but no nematodes were found in the tissues.

(*b*) *Older palms.*

Inoculations of four-year-old palms were carried out in the field by burying large pieces of red ring tissue among the roots near their bases. Three palms so treated on May 27th showed no red ring tissue when bored on July 15th, but by August 19th they showed early leaf symptoms and the presence of red ring was confirmed by boring. This experiment was then repeated, three more palms having diseased tissue buried among their roots on August 19th. Again, on September 2nd, three more palms were inoculated by pouring water containing nematodes into a shallow trench dug around the base of the trunks. On October 7th, though no external symptoms had appeared, roots from one palm of each of these two latter sets of inoculations were dug up. Some of them were obviously discoloured and eelworms were plentiful in them. On October 21st all six palms were bored, and although no external symptoms were yet visible, one of each set of three was found to contain red ring tissue.

On the same day samples of soil, containing portions of the finer roots, were dug up from near the base of the two palms showing red ring tissue, and the soil (a very sandy loam) was sifted, separating the roots and lumps of soil from the bulk of the finer soil. In the case of the palm around which water with nematodes had been poured, a few individuals of *A. cocophilus* were found in the fine soil separated from roots, and also in the siftings containing pieces of fine root, but other species of nematodes were more prevalent. In samples of soil in which pieces of diseased tissue had been buried, *A. cocophilus* could not be found, though other species of nematodes were plentiful.

All but one of these root-inoculated palms subsequently developed external symptoms, at varying times during November, showing that infection by this route is slower than through the leaf axils or stem. One of the last series (eelworms in water added to the soil) did not become infected and was still healthy on December 16th.

(c) *Conclusions from root inoculation experiments.*

It would appear from these experiments that *A. cocophilus* does not build up large concentrations in the soil, as some of the earlier investigators believed ; hence their recommendation of isolation trenches. It would seem, moreover, that although root infection can be brought about artificially and might occasionally take place naturally, it is not a normal method of initiation of the disease ; for in the ordinary course of events the nematodes would not find their way into the soil or persist there in sufficient numbers to give a reasonable chance of infection. If a persistent source of inoculum is present (e.g. buried red ring tissue, which has been found to remain quite fresh for two weeks after burial), or if a high concentration of *A. cocophilus* is brought about by adding it in water to the soil, the nematode presumably gains entry through damaged or senescent roots. It then multiplies in the tissues, and eventually works its way up into the trunk, producing the usual symptoms. Failure to secure infection of roots of seedling palms in water may have been due to a too short exposure, or to the preference of the nematodes for the water rather than the root tissues. Failure to infect palms in tubs may have been due, in part, to lack of enough senescent larger roots to give entry, and to absence of suitable tissue in these young palms for the nematodes to multiply.

Natural Transmission of The Disease

It has been suggested that the nematodes travel from one palm to another in continuous films of water during rain, flooding or the presence of heavy dew. At Cocal this was demonstrably not the case. The disease spread with equal rapidity in the dry season when, moreover, owing to the proximity to the sea, there is very little dew, and was if anything more extensive on higher and better drained land near the sea than on swampy land near an adjoining river.

On the other hand it has always been the opinion of observant planters in Trinidad that the Coconut weevils *Rhynchophorus palmarum* and

Rhina barbirostris play a part in spreading the disease. They are readily attracted to young palms by the fermentation of small quantities of sap exuded from the slightest injury to the soft tissues. Older, hardened palms do not attract them unless more extensively damaged. Ashby (1924) made reference to the reported transmission of the eelworm on the snouts of coconut weevils in Central America, and it is evident that where these weevils abound the disease is more prevalent than where they are scarce. The East Coast Coconut areas (Nariva, Mayaro, Guayaguayare), where red ring has been so much in evidence, suffered from lack of attention during the war years and the weevils have become very abundant there. On the other hand in the Cedros area, where the disease was originally observed, it is of no account, and apparently caused no serious loss in the areas replanted after the 1933 hurricane ; but coconuts there are mostly estate grown and active steps have always been taken to check weevils. Similarly, in Tobago the disease is of little importance on the well managed plantations at the South-East end of the island, but does considerable damage in neglected coconut plantings elsewhere. Finally, it has been remarked (Briton-Jones, 1940) that coconuts established through cane, as opposed to secondary bush, seldom contract the disease. In this environment the necessarily clean surrounding cultivation leaves no breeding place for coconut weevils.

It was therefore considered desirable to investigate the possible action of coconut weevils as vectors of the disease, the moreso as it had been recently stated (Tidman, 1951) that in Brazil infection was spread by *R. palmarum* feeding on diseased tissue and carrying the nematodes in its intestines and faeces. It subsequently transpired that the report on this means of transmission was based on inaccurate information, but in the meantime experiments were carried out in Trinidad to test the validity of this alleged method of transmission. Firstly, weevils obtained from the leaf bases of diseased palms and then placed in jars with red ring material were subsequently dissected, but no nematodes could be found in them or in their faecal pellets. Large pieces of infected tissue, which would inevitably attract weevils, were left on the ground under young palms, but no infection occurred. Plastic bags were devised to hold wedge—shaped portions of infected tissue and allow access of weevils whilst preventing the direct escape of nematodes in moisture. Three of these bags were placed in leaf axils of each of four palms and left there for two weeks, but though weevils visited the contents, and would then go into the leaf axils, no infection resulted. It is therefore evident that direct transmission by the mouth parts or through the intestinal tract does not take place.

It was observed, however, at Nariva-Cocal that *R. palmarum* was always present in large numbers and was often found in the leaf axils of the palms, especially those of the bottom leaves. The larvae were invariably found tunnelling in the stems of any diseased palms felled and left lying, and sometimes in the stem bases of palms still disease-free, the eggs apparently having been laid by adults attracted by some injury at the base of the stem and entering thereby. Though *Rhina barbirostris* was seldom seen on this

plantation, it was quite abundant in the Mayaro area, where planters reported it to be readily attracted even by the slight ooze of sap following the partial or complete removal of a leaf from its stem attachment, either in the course of agricultural operations or otherwise.

At Cocal, two diseased palms were cut down and left lying to attract *R. palmarum*. These were visited on the evening of the day after felling, and it was noted that weevils had by then burrowed into the diseased tissues. When removed they were covered with small pieces of débris, all heavily colonised by *A. cocophilus*. In one experiment, two such weevils were placed in a hole bored in the trunk of a healthy palm, confined there by gauze tacked over the hole, and removed after about 12 hours. In two other experiments, weevils taken from diseased tissue in which they were burrowing were kept overnight in a tin containing pieces of red ring tissue, and the following morning placed in holes bored in healthy palms and left for a day. Within two months all three palms showed red ring symptoms. One was then cut down and the trunk found to contain a number of larval tunnels of *R. palmarum*, caused by the progeny of weevils attracted to the wound made for insertion of the insects at the start of the experiment. Several adults were found burrowing in the débris of these tunnels, which were in the red ring area. Two covered as before with infected débris, were removed and placed in holes bored in the trunks of two healthy palms. The weevils were again confined to the holes by gauze, and in this case left there, the cover being maintained over the holes. These palms were examined four weeks later by borings with brace and bit, and both found to have red ring.

It is evident, therefore, that the disease *is* spread by the coconut weevil acting as a carrier of infected débris, rather than of individual nematodes. It is to be expected that those carried on the surface of the insect without protecting plant tissue will die from desiccation, and there is no evidence for transmission of nemas on mouth parts or their survival in the faeces. Thus weevils merely feeding on the surface of infected tissue will not act as vectors, but after burrowing in diseased tissue and becoming covered with débris, they do. The débris-covered weevils may enter holes made by other weevils, transmitting the disease in the manner of the experiment, but doubtless more generally they fly to adjacent palms and crawl down into the leaf axils (usually those at the base of the palms, but sometimes higher ones) depositing there pieces of diseased tissue, from which infection can take place. It is noticeable that most new infections arise in palms immediately adjoining those already diseased ; weevils taking longer flights probably lose much of the débris when in the air, but the periodic occurrence of new outbreaks in hitherto unaffected areas can be accounted for by the retention of some of it.

Urich and Guppy (1911) made some 'preliminary' observations on *R. palmarum* in Trinidad, and found that the time from egg laying to moulting of the larvae in two instances was 74 and 128 days respectively, and from formation of the cocoon to emergence of the perfect insect 59 and 33 days respectively, indicating a life cycle of about four to five months. The larvae

tunnel in the soft tissues of the cortex, which soon rot in a dead palm, but the cocoons are found near the periphery of the stem, i.e. in the red ring area, and the adult emerges through the outside of the stem. Portions of trunk from a diseased palm, cut down on June 19th and left in the field, were brought to the laboratory on July 10th, by which time they contained many larvae. They were placed in an insect cage in a shaded spot, to see if adults could be obtained. The cage was exposed to rain, and being also shaded, the stem pieces rotted too quickly for completion of the life cycle. Despite this, when a piece of the softened periphery of the stem, in which the cortex had entirely rotted, was cut open on October 9th, traces of red ring were still to be seen, and a few live individuals of *A. cocophilus* were found, although other species of nematode were present in much larger numbers. It is, therefore, evident that in the field, especially in the absence of shade, the life cycle may be completed and adult weevils emerge from the trunks of diseased palms with *A. cocophilus* still present. Therefore the nematode may also be carried in débris on the bodies of emerging adults.

Whether other insects can carry infected débris similarly is a matter for speculation. Ants have been suggested as vectors of the disease in Venezuela (Bain and Fedon, 1951), though the method of transmission was not specified. They do not appear to play such a part in Trinidad.

Alternative Hosts

The literature contains reference (Goodey, 1940) to the disease having been found on a date palm and on oil palm in the Trinidad Botanic Gardens, the reference quoted being the Annual Report of the Trinidad Department of Agriculture for 1925. Search in this and contemporary reports has, however, failed to discover the reference.

Nowell (1924) reported having successfully inoculated the cabbage palm (*Oreodoxa oleracea*) and obtained rapid death, and another successful inoculation of this species has been reported to the writer ; but, on the other hand, this palm, a native of Trinidad, grows plentifully in the Nariva swamp immediately adjoining the plantation where these investigations were carried out, and remains unaffected, presumably because *Rhynchophorus* does not attack it. Nowell also reported successful though slow infection of the gru-gru palm (*Acracomia aculeata*), another common native palm in Trinidad, but in this case too natural infection is never observed. He also referred (1923) to the natural occurrence of one case of the disease on an unidentified species of *Cocos* and it seems possible that such might arise from a chance infection due to *Rhynchophorus*.

Red ring would, therefore, appear for all practical purposes to be confined to the Coconut. The nematode appears to have no means of prolonging its existence outside this palm, and no resting stage has been discovered. The origin of the disease on the mainland and the possibility of a wild-palm host

there must remain a matter for speculation. Its appearance in the southern islands of the Lesser Antilles can, with reasonable probability, be attributed to its having been seaborne from the mainland by floating stems of diseased palms in which the nematode had remained viable.

Control of the Disease

This can be effected by removal of sources of infection and reduction in the number of coconut weevils. Proper phytosanitation achieves both ends. The first essential (and it may be noted that this operation was recommended, amongst others, by Nowell in 1920) is the *effective* destruction of red ring infected tissue by fire, unless it can be conveniently buried where it cannot be a cause of abnormal root infection. However, the trunk of a young coconut palm contains a high percentage of water, and fire applied to the outside scarcely affects the inner tissues. Diseased trunks must be cut down flush with the ground, or, better still, cut off from the roots and removed from the soil entirely, which is not too difficult with young palms on sandy soil. The trunks must be cleaned of the attached leaf bases and cut up into lengths of about two feet, which must then be split lengthwise, so that the axe cuts expose the red ring area. These pieces and the rest of the debris should then be heaped up, on top of the stump if one is left, and burnt. By using coconut husks, with paraffin to start fire, this can be done effectively, though it is generally necessary to burn at least twice to ensure that no infective red ring tissue is left.

This control measure, besides removing the only source of infection, removes the main breeding ground of the weevils. (As has been pointed out above, roots left in the soil are of no consequence.) If it has to be done in an area where the disease has been allowed to become widespread, initial expense is high ; but once the work is completed, it is only necessary to keep a look out for new cases, resulting from infection brought from sources outside the plantation, and deal with them immediately. Just after the initial clearing, of course, a number of infected palms that were symptomless when the others were cut may manifest the disease, and the operation of felling and cutting in a badly diseased field with weevils present can, by disturbing them, cause new infections. The danger, once thought to occur, of spreading the disease by chips flying from the axe when felling affected palms, is non-existent, since soil infection does not result. The chips cannot be carried by weevils, and they soon dry out, resulting in the death of the nematodes inside.

The effectiveness of control by proper destruction of diseased palms was indicated in two fields of young palms of susceptible age at Cocal, in which only a few instances of the disease had occurred when the appropriate action was taken. These infected palms were cut and burnt in August and September. One subsequent case appeared in each area late in September, after which no more diseased palms were seen in either field up to the end of December. Complete destruction of diseased trunks has also been reported to give successful control in Brazil (Ferreira Lima and Marques da Cruz, 1945).

The possibility of using a systemic pesticide was considered, and a few experiments were carried out with proprietary substances, which failed, however, to kill the nematodes in the stems of affected palms. The most promising line of attack, if a suitable chemical could be found, would be the prophylactic treatment of palms in the immediate neighbourhood of infected ones. Once a palm shows external symptoms the nematode population in the red ring area is such that destruction of the nemas with concomitant survival of the palm (which will by then have almost ceased growing) seems most unlikely. Moreover, if the nematodes were killed and the palm died, although the immediate source of infection would be removed, the dead palm would become a breeding place for coconut weevils when the pesticide in the tissues had broken down.

Acknowledgments

My thanks are due to Mr. W. T. Dale of the Imperial College of Tropical Agriculture for reading this paper in draft and making many helpful suggestions, and to Mr. R. G. Fennah of the Imperial College of Tropical Agriculture, who had begun investigating this disease when with the Department of Agriculture, and with whom many aspects of it were discussed.

REFERENCES

Ashby, S. F. (1921–a). Some recent observations on Red Ring Disease. *Agricultural News*, **20**, 334.

——————(1921–b). *Ibid*, 350–351.

——————(1922). Experiments on Red Ring disease of Coconut in Grenada. *Agricultural News*, **21**, 94–95.

Ashby, S. F. and Nowell, W. (1924.) Red Ring disease of Coconuts. *Proceedings of the Ninth W.I. Agricultural Conference, Jamaica*, 1924, 164–172.

Bain, F. M. and Fedon, S. A. (1951). Investigaciones sobre Anillio Rojo del Cocotero. *Agronomia Tropical, July–September*, 1951, *Maracay, Venezuela*. (Translation of summary seen only).

Briton–Jones, H. R. (1940.) The Diseases of the Coconut Palm. *Bailliere, Tindall and Cox, London.*

Cobb, N. A. (1919). A newly discovered nematode, *Aphelenchus cocophilus*, n.sp. connected with a serious disease of the Coconut Palm. *W. I. Bulletin*, **17**(4), 203–210.

Ferreira Lima, A. D. and Marques da Cruz, H. (1945). O anel vermelho do coqueiro. *Bol. Fitossanitario, Rio de Janeiro*, **2**, 87–114.

Goodey, T. (1940). The Nematode parasites of plants catalogued under their hosts. *Imperial Bureau of Agricultural Parasitology (Helminthology).*

Joffilly, J. M. (1948). A doença do anel vermelho do coqueiro e sua ocorrência no Brasil. *Serv. Nac. Pesq. Agron. Rio de Janeiro. Bol.*, **3**, 64 pp.

Nowell, W. (1918). Root disease of Coconut Palms in Grenada. *Agricultural News*, **17**, 398–399.

——————(1919–a). The Root Disease or Red Ring Disease of Coconut Palms. *Agricultural News*, **18**, 46.

——————(1919–b). Red Ring Disease of Coconuts. *Ibid*, 398.

——————(1923). Diseases of Crop Plants in the Lesser Antilles. *The West India Committee, London.*

Tidman, D. A. (1951). Agricultural and Horticultural Problems of Brazil. *World Crops*, **3** (9), 341–344.

Urich, F. W. and Guppy, P. L. (1911). Preliminary notes on some insects affecting the Coconut Palm. *Circular No. 5, Board of Agriculture, Trinidad and Tobago*, 31 pp.

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NOTES ON THE BANANA BUNCH

By

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Summary

The relations between numbers of hands and numbers of fruits and between numbers of hands and the count percentage in the Gros Michel banana are defined by means of regression equations.

1. Introduction

The infructescence of the banana is called a *stem ;* it is composed of *hands* which are nodal clusters of fruits or *fingers*. The number of hands is called the *grade*. A nine-hand stem is called a *count, count-bunch* or simply *bunch* and is the normal basis for banana buying. The bunch, together with larger stems of 10 hands or more, receives the ruling standard price ; eight-hand stems receive three-quarters of the standard price, seven-hand stems one-half and six-hand stems one-quarter ; stems bearing five hands or fewer are not normally saleable for export. The *count-percentage* or *grading* of an estate, field, crop, &c. is reckoned as an arbitrarily weighted mean, thus :

$$100\left\{\frac{n_9 + \frac{3}{4}n_8 + \frac{1}{2}n_7 + \frac{1}{4}n_6}{n_9 + n_8 + n_7 + n_6}\right\} = 100\left\{\frac{4n_9 + 3n_8 + 2n_7 + n_6}{4N}\right\}$$

where n_9 = number of stems with 9 hands or more, n_8 = number of stems with 8 hands and so on, and N = total number of stems in the sample.

The purpose of this note is to relate grade to number of fruits and to count percentage. The data used were all abstracted from the records of banana breeding operations ; they derive from records of pollination of the Gros Michel banana in four localities in Jamaica, British West Indies, and at the Imperial College of Tropical Agriculture, Trinidad.

2. The Relation Between Grade and Number of Fruits

Results are summarized in Table 1. The first three localities named were private estates on which the Banana Research Scheme used certain fields for pollinations ; the plants were subjected to normal commercial pruning. The fourth locality, Bodles, is the present banana breeding station and there the plants were subjected only to a very light pruning since experiments had shown that seed yields could thus be improved (Shepherd, 1953). The Trinidad plants were also unpruned.

TABLE 1—*Data on numbers of hands and numbers of fingers in the Gros Michel banana*

LOCALITY	Number of Stems	Hands per Stem (H)	Fingers per Stem (F)	Fingers per Hand (F/H)	r_{FH}	b_{FH}	a
Brimmer Hall, Jamaica	690	7.07±0.041	105.7±0.84	14.95	0.9633	+19.63±0.2090	−33.1
Potosi, Jamaica	786	7.30±0.033	114.1±0.66	15.63	0.9716	+19.57±0.1573	−28.8
Holland, Jamaica	244	8.33±0.065	140.1±1.42	16.82	0.9441	+20.51±0.4621	−30.7
Bodles, Jamaica	200	7.37±0.057	107.7±1.01	14.61	0.8615	+15.30±0.6408	− 5.1
I.C.T.A., Trinidad	189	5.79±0.077	65.8±1.85	12.23	0.8910	+21.38±0.7963	−57.8

Stems with seven to eight hands bear upwards of one hundred fruits, and average fourteen to seventeen fruits per hand. This average, of course, conceals the fact that there is some variation within the stem ; the basal hands bear more numerous fruits than the upper ones, thus (Gros Michel from Bodles) :—

Hand number ...	1	2	3	4	5	6	7	8
Mean numbers of fingers	16.9	17.2	16.0	15.7	14.9	14.6	14.3	14.0

Wardlaw, Leonard & Barnell (1939) give similar data. Correlations between fingers and hands are high and regressions of fingers on hands range from 15 to 21. This means that each additional hand adds from 15 to 21 fingers to the total. In every case this regression coefficient exceeds the mean number of fingers per hand and therefore from the equation

$$F = a + bH$$

(where **F** = number of fingers, **b** = the regression coefficient, **H** = number of hands and **a** is a constant)

$$F/H < b$$

and

$$a < O$$

In other words, an increment of one hand involves not merely the addition of the fingers in that hand but also an increase in the mean number of fingers in the other hands.

Popenoe (1941) gives data for Honduras fruit from which can be calculated :

$$F = 22.65\ H - 59.32$$

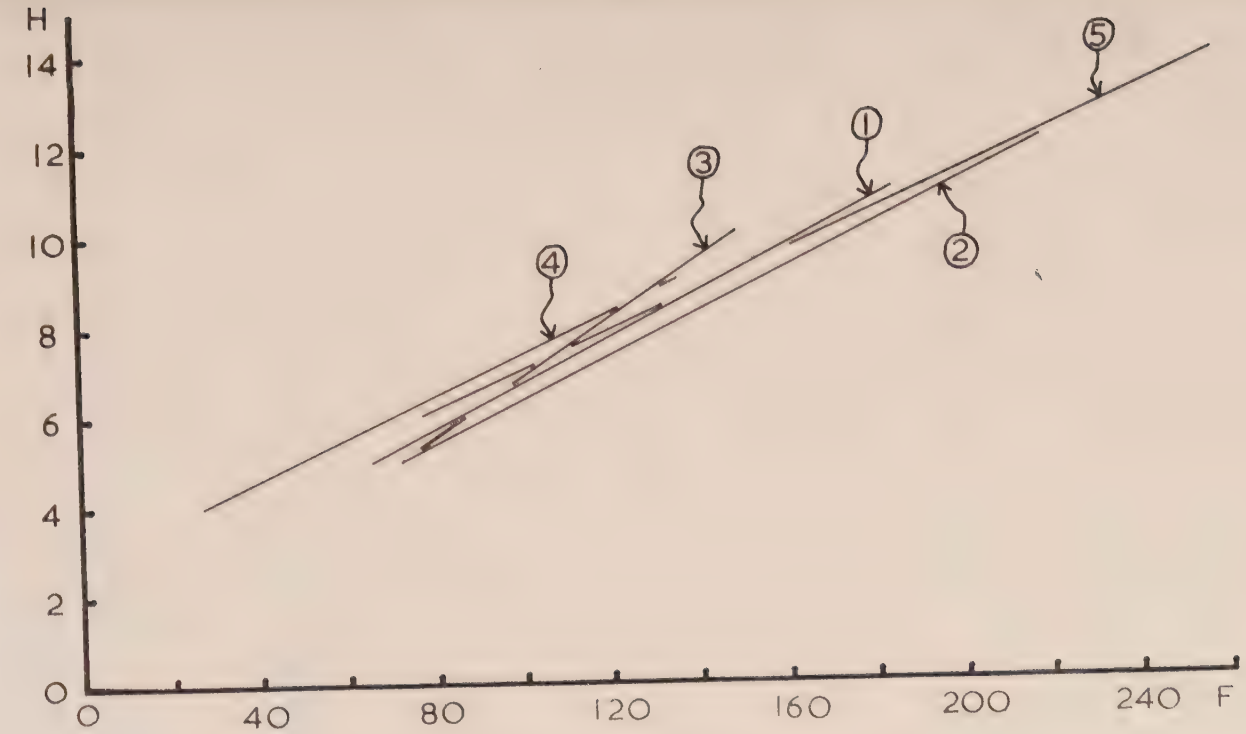
an equation which agrees rather closely with that calculated for Trinidad fruit. Popenoe's data, incidentally, are evidently readings from a fitted straight regression line.

There are real differences between the various regressions. Bodles is significantly lower than any other and the difference between Holland and Potosi approaches significance. Potosi and Brimmer Hall do not differ. The Honduras regression lies outside the fiducial limits of all the Jamaican samples but agrees well with the Trinidad data. Thus the regression varies with environment and the use of a regression equation for purposes of prediction should obviously only be attempted when the necessary statistics for that particular locality or crop are known. Results are shown graphically in Fig. 1, data for Potosi and Brimmer Hall having been combined together as one line.

3. The Relation Between Grade and Count Percentage

The count percentage has been stated above to be an arbitrarily weighted mean in which the scores 1, 0.75, 0.50, 0.25 and 0 are applied to stems with 9 or more, 8, 7, 6 and 5 or fewer hands respectively. So long as there are no stems with more than nine or fewer than six hands in any sample, the

Fig. 1

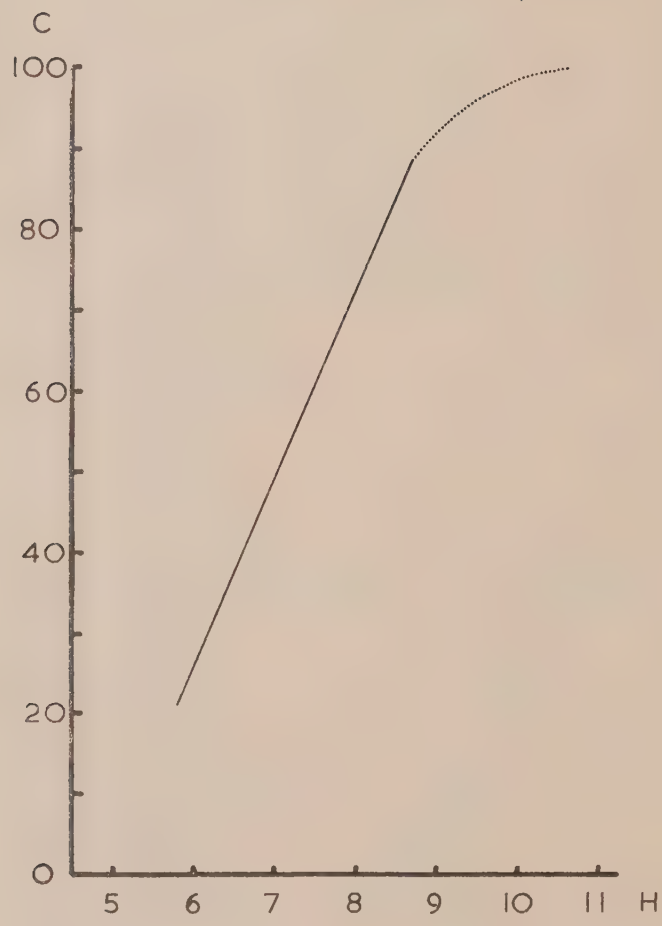


Regressions of numbers of fingers (F) on numbers of hands (H) in the Gros Michel banana

1 [illegible] 2 Holland 3 Bodle [illegible]

[illegible] Honduras (after Popenoe, 1911)

FIG. 2



Regression of number of hands (H) on the Count percentage (C) of samples of the Gros Michel banana. Solid line—Fitted straight regression line ; dotted line—curve estimated from Jamaican data and fitted by eye.

expected relation between mean number of hands (**H**) and count percentage (**C**) is evidently :—

$$\mathbf{C} = 25\,\mathbf{H} - 125$$

and $$\mathbf{H} = 0.04\mathbf{C} + 5$$

The occurrence of stems outside the range 6–9 would tend to decrease the regression of **C** on **H**, to increase that of **H** on **C**, and, at the limits as **C** approaches 25 and 100 per cent., to cause curvature of the line.

Thirteen samples of fifty stems each were taken randomly from the Jamaican data used here and from them were calculated :—

$$\mathbf{C} = 23.78\,\mathbf{H} - 116.8$$
$$\mathbf{H} = 0.042\,\mathbf{C} + 4.92$$

$\mathbf{r} = 0.9988$, S.E. $(\mathbf{b}_{CH}) = 0.3499$, S.E. $(\mathbf{b}_{HC}) = 0.0006193$ and hence the fiducial limits of $\mathbf{b}_{CH} = + 0.7698$ and of $\mathbf{b}_{HC} = + 0.001363$. The calculated regressions do differ from expectations and in the expected directions. Over the range of sample means studied (roughly 6 to 8.6 hands) the data fitted a straight line very accurately as judged by the high correlation coefficient and examination of the plotted points. Results are shown as a solid line in Figure 2 to which has been added a dotted line indicating the expected deviation from linearity at the upper limit of the range sampled. Thus mean numbers of hands may safely be transformed to count percentages and *vice versa* within the range 6 hands and 25 per cent. Count and 8.6 hands and 88 per cent. Count but not outside this range.

REFERENCES

Popenoe, W., 1941. Banana culture around the Caribbean. *Trop. Agric., Trin.*, **18**, 8–12.

Shepherd, K., 1953. The fertility of the Gros Michel banana. *J. Pomol. and Hort. Sci.* (in the press).

Wardlaw, C. W., Leonard, E. R., and Barnell, H. R., 1939. Studies in tropical fruits. VII. Notes on banana fruits in relation to studies in metabolism. *Ann. Bot. Lond. N.S.*, **3**, 845–860.

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PRELIMINARY SURVEY OF INTERNAL PARASITES OF ANIMALS IN St. KITTS, B.W.I.

By

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As far as the writer is aware no list of internal parasites of animals has been compiled for the island of St. Kitts. A preliminary survey has, therefore, been made, and, while the submitted list is not complete, an attempt at classification has been made.

Specimens were recovered from carcases in the Public Markets in the cases of cattle, sheep, goats and swine. The identification of specimens from horses, dogs and poultry was made at post-mortem examinations and from faecal examinations.

A.	Dog	(1) *Ancylostoma caninum*	(4) *Dipilidium caninum*
		(2) *Toxocara canis*	(5) *Trichuris vulpis*
		(3) *Toxascaris leonina*	(6) *Taenia* sp
		(7) *Dirofilaria immitis*	
B.	Horse	(1) *Oxyuris equi*	(3) *Strongylus equinus*
		(2) *Strongylus vulgaris*	(4) *Ascaris equorum*
C.	Sheep and Goat	(1) *Haemonchus contortus*	(4) *Trichostrongylus* sp
		(2) *Moniezia* sp	(5) *Trichuris ovis*
		(3) *Oesophagostomum* sp	(6) *Dictyocaulus* sp
D.	Pig	(1) *Ascaris lumbricoides*	(3) *Metastrongylus apri*
		(2) *Stephanurus dentatus*	
E.	Cattle	(1) *Haemonchus contortus*	(4) *Trichostrongylus* sp
		(2) *Dictyocaulus vivaparus*	(5) *Oesophagostomum* sp
		(3) *Ostertagia ostertagi*	
F.	Poultry	(1) *Oxyspirura mansoni*	(2) *Ascaridia galli*

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REFERENCES

Vaughan, A. W. (1952) *Vet. Rec.* 31. 454.
Lapage, G. *Personal communication.*

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LITTLE LEAF DISEASE OF THE OIL PALM (*ELAEIS GUINEENSIS*) IN THE BELGIAN CONGO

Part 2

BY

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Summary

A report is given on an outbreak of Little Leaf disease in an agronomical replanting experiment. The evidence concerning the distribution of affected palms in this experiment suggests that Little Leaf is most probably a physiological disease.

The results of a study of leaf growth in healthy and Little Leaf palms are included, and a method for determining the latest possible date at which palms first became affected by Little Leaf is described. The application of this method to determine when the Little Leaf palms in the replanting experiment were first affected, suggests that the disease is not correlated with the occurrence of a long dry season.

Introduction

In a previous paper (Kovachich, 1952) it was concluded that Little Leaf disease of the oil palm is either of physiological or virus origin. More recently, evidence has been obtained, incidentally, from an agronomical replanting experiment, supporting the view that the disease is probably physiological.

There is a delay between the time when the palms are first affected by Little Leaf and the appearance of external symptoms. It was, therefore, considered that a method for determining this delay should be evolved, so that the date when the palms in the replanting experiment were first affected could be estimated. In this way it was hoped to determine whether a correlation existed between the outbreak of the disease and the dry season.

Replanting Experiment

This experiment was designed by Mr. J. D. Ferwerda (Agronomist, Huilever S.A.).

(*a*) *Details of the experiment*

The aim of the experiment was to determine the best method for replanting old plantation blocks with young oil palms. Four treatments were included, namely :—

A The old palms were felled before the young palms were planted. No fertilizer was applied.

B The young palms were planted between the lines of old palms. Fertilizer was applied.

AB The old palms were felled before the young palms were planted. Fertilizer was applied to the young palms.

I The young palms were planted between the lines of old palms. No fertilizer was applied.

The design of the experiment was a 4 x 4 Latin square with 78 palms per plot, a total of 312 palms per treatment.

The fertilizer applied was based on Homes' Formula No. 3 (1949) but various minor elements were added. The following elements were included in the fertilizer :—N, P, K, Mg, S, Ca, B, Co, Ni, Zn, Mo. Fertilizer applications after September, 1951, contained only N, K and S.

The young palms were planted during November, 1948.

(*b*) *Incidence of Little Leaf in the young palms*

When the young palms were examined during April, 1952, i.e., 3½ years after transplanting, it was found that many of them had abnormal leaves. Some leaves had only abnormal distal pinnae. Other palms showed similar abnormalities of the older leaves, but succeeding leaves were more seriously malformed and of the typical Little Leaf type. The number of abnormal open leaves present on the palms varied between 1 and 18, with 7–11 being most common. Two palms were dead as a result of the disease.

Palms with the abnormality of the leaves restricted to the distal pinnae were designated Little Leaf degree 1 ; those with typical Little Leaf type leaves (with or without rotting) Little Leaf degree 2, and palms, which had died as a result of the disease, Little Leaf degree 3. The incidence of Little Leaf disease is shown in Table 1.

TABLE 1—*The incidence of Little Leaf palms in the replanting experiment*

Treatment	Degree of Little Leaf	Number of Little Leaf Palms				
		Plot 1	Plot 2	Plot 3	Plot 4	Total
A	1	7	9	0	3	19)
	2	1	2	0	1	4)23
	3	0	0	0	0	0)
B	1	10	10	1	3	24)
	2	12	10	3	0	25)49
	3	0	0	0	0	0)
AB	1	12	17	19	21	69)
	2	43	24	22	12	101)172
	3	2	0	0	0	2)
I	1	1	0	1	0	2)
	2	0	0	0	1	1) 3
	3	0	0	0	0	0)

PLATE 2—Distorted leaves from a young Little Leaf palm.

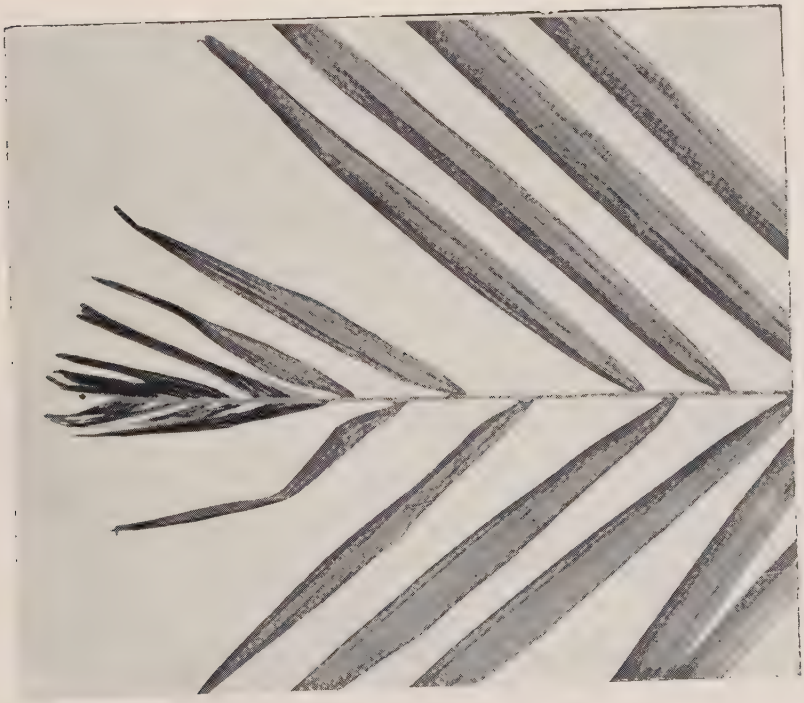

PLATE 1—Abnormal distal pinnae from a young palm with Little Leaf.

PLATE 4—L.N. of the crown region of a young palm killed by Little Leaf disease.

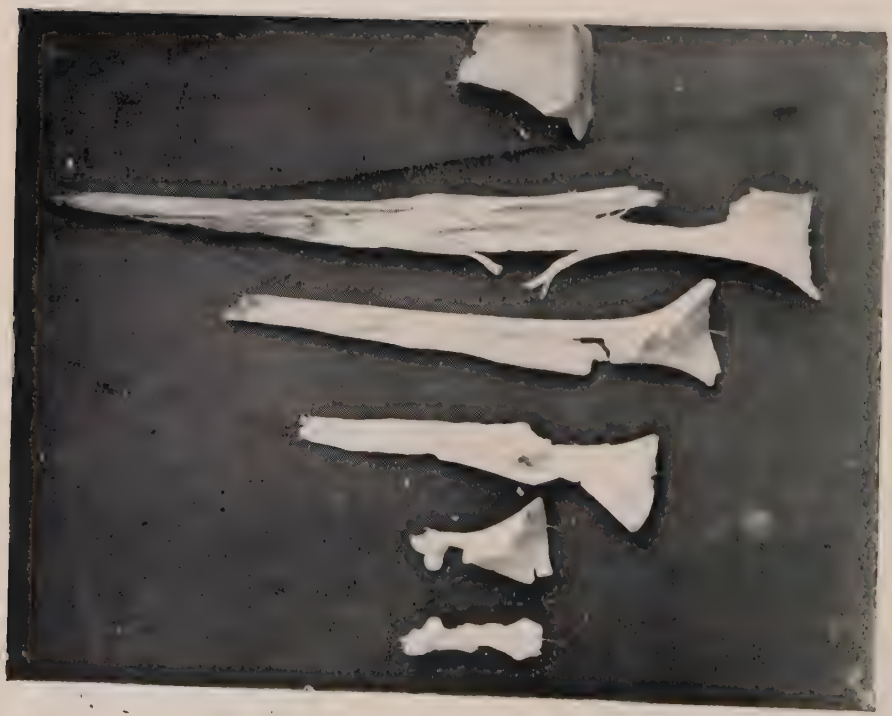

PLATE 3—Closed, young, distorted leaves from a young Little Leaf palm.

When the numbers of affected palms are expressed as percentages of the total palms standing, the following figures are obtained :—

Treatment A	7.5 per cent. of the palms affected
Treatment B	19.6 per cent. of the palms affected
Treatment AB	61.5 per cent. of the palms affected
Treatment I	1.2 per cent. of the palms affected.

(c) *Examination of affected palms*

(i) *Degree* 1. The distal pinnae were considerably shorter than normal and more crowded on the leaf rachis than were the median pinnae, suggesting that the leaf rachis had not fully elongated (Plate 1.) The abnormal pinnae showed no signs of attack by insects or micro-organisms.

Many leaves were commonly so affected on the same palm but normal leaves were frequently produced after the abnormal ones.

(ii) *Degree* 2. These palms first produced leaves with abnormal tips, as described above. These were followed by smaller, badly distorted leaves. The pinnae were frequently corrugated, or lacking, and a callus layer was commonly present close to the surface of the rachids. Typical malformed leaves are illustrated in Plate 2. On dissecting affected young palms, it was found that young unopened leaves enclosed within the central frond cylinder of some were also malformed and identical in all respects, except size, with those found in mature palms affected by Little Leaf. Plate 3 illustrates the young, malformed leaves from a young palm.

Many of the affected palms had recovered and were producing apparently healthy leaves. Some palms showed symptoms of several separate attacks, which had been followed by apparent recoveries.

Although many palms were observed with some rotting of the pinnae, in general this was slight, and relatively few palms displayed rotting of the rachids. Micro-organisms were present in the rotted pinnae, but it is considered that they were not pathogenic but had invaded already necrosed tissues.

(iii) *Degree* 3. Palms killed by the disease had first produced typical Little Leaves. The young leaves of the bud and the apical meristematic region had been completely rotted. A hard callus layer separated the healthy tissue from the rotted parts (Plate 4) and some of the tissues of the " cabbage " region were a dull red colour.

Arrested roots were present in all seriously affected palms examined, but some roots were normal.

The growth of the leaves was studied by comparing successive leaves of several palms from the replanting experiment. The petiole, pinnae-bearing part of the rachis, and the distal pinnae of each leaf were measured. As there was considerable uniformity in the results obtained, only a single, typical example of each type of palm is given.

For the purpose of identifying the individual leaves, they were numbered from the oldest closed leaf. The opened leaves were given Roman and the closed leaves Arabic numerals. Thus, the youngest open leaf was No. i and the oldest closed leaf No. 1. The measurements of the various leaves are given in Table 2.

(*a*) *Healthy palms*

The growth of the pinnae was extremely rapid between leaf No. 7 and leaf No. 5 and the latter had fully grown pinnae. The elongation of the rachids commenced after leaf No. 6, whilst the elongation of the petiole coincided with the opening of the leaves and continued until the leaves occupied position No. iii.

(*b*) *Little Leaf palms*

Pronounced growth irregularities were present in the pinnae of some leaves, i.e., leaves No. ii, iv and v in the example given. Both the rachids and the petioles of affected leaves were commonly not fully grown, as can be seen in the measurements given for leaves No. i and No. ii (rachids) and leaves No. iii and No. iv (petioles).

There is also evidence that the opening of the leaves was delayed in the affected palms. Thus pinnae growth was greatest between leaf No. 8 and leaf No. 7, as compared with between leaf No. 6 and No. 5 in healthy palms, and the elongation of the petiole started at leaf No. 3 and not at leaf No. 1 as in healthy palms.

Similar differences have also been observed between the leaf development of ten-year-old healthy and Little Leaf palms.

(*c*) *Deductions*

As the pinnae are fully grown in leaf position No. 5, any growth abnormality of the pinnae must occur before the leaf occupies this position. At the onset of the disease, all the developing leaves, which become distorted, are affected at the same time. Thus, it is probable that the oldest leaf with distorted pinnae occupied leaf position No. 6 when growth was affected, i.e., the pinnae were in the final growth stage.

The delay between the time when the palm is first affected and the opening of the first abnormal leaf is, therefore, equivalent to at least the time required for the production of six leaves.

TABLE 2—*Measurements of Successive Leaves from Healthy and Little Leaf Three-Year-Old Palms—(in cms.)*

	LEAF NUMBER																	
	v	iv	iii	ii	i	1	2	3	4	5	6	7	8	9	10	11	12	13
HEALTHY—3 YRS.																		
Distal Pinnae ...	37	36	39	36	36	38	34	35	34	37	8	2.5	0.6	0.4	0.2	0.1	0.1	—
Rachis	200	209	208	211	212	187	156	110	66	17	5	2	1.8	1.4	1.0	0.8	0.5	0.3
Petiole	70	69	72	57	25	9	5	4.5	4	4	4	3.5	3.5	3.0	2.8	2.5	2.4	2.2
LITTLE LEAF—3 YRS.																		
Distal Pinnae ...	0	0	32	0	31	26	31	26	34	35	28	31	8	2.5	1.7	1.0	0.5	0.2
Rachis	209	228	190	93	83	105	90	70	45	42	22	6	3.2	2.5	1.5	1.0	1.0	1.0
Petiole	76	65	59	75	53	35	21	8	5	4.5	4.5	4.0	3.5	3.5	3.2	3.0	3.0	2.8

The rate of leaf production is known for the palms of the replanting experiment, and efforts were made to determine whether the time when they were first affected coincided with the change in the fertilizer application (September, 1951), or with the dry season (June, July and August). The position of the oldest leaf with abnormal pinnae growth was determined for all Little Leaf palms. The number of leaves produced by the palms, since these first abnormal leaves occupied leaf position No. 6, was then calculated. The time necessary for this leaf production was estimated, based on the leaf production rate of the palms for each treatment.

The position of the oldest leaf with abnormal pinnae in the affected palms is shown in Table 3, and Figure 1 illustrates the distribution of Little Leaf palms against the latest possible date when the palms could have been affected.

The results of these observations show that the majority of the palms were affected prior to the change in the fertilizer application and, therefore, this change cannot be responsible for the disease. There is also, no evidence to suggest that the disease is induced by the occurrence of a long dry season.

Discussion

The similarity of the symptoms displayed by the young Little Leaf palms of the replanting experiment and adult Little Leaf palms is so great that there can be little doubt that both conditions were due to the same cause. The observed differences are considered to be only differences of degree, and may be accounted for by the difference in age of the palms.

The disease census of the experimental plots shows conclusively that the disease was influenced by certain cultural treatments. Both fertilizing the young and felling the old palms had the effect of increasing the incidence of the disease in the young palms, which also had a higher growth rate as a result of these treatments. However, the fertilized palms grown under shade had a lower growth rate but a higher incidence of the disease than the palms grown without fertilizer and without shade. Thus, although the growth rate of the palm influenced the incidence of the disease, it would appear that the fertilizer has also had the effect of increasing the incidence of the disease in some way apart from stimulating growth. It would therefore appear that the fertilizer application created a deficiency or an unbalance of nutrients.

The estimation of the time when the palms were first affected by Little Leaf, although not absolute, suggests that most were affected during the period September, 1950 to July, 1951, with the peak occurring during March, April and May, 1951, immediately before the dry season. This is what would be expected in view of the relationship between a high growth rate and the incidence of the disease.

TABLE 3—*Leaf Position of the oldest Leaf with abnormal Pinnae in the young Palms of the replanting Experiment*

TREATMENT	No. of Palms																															
Open Leaf position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
A	—	—	1	1	1	4	1	2	4	2	2	2	1	1	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
B	—	—	—	3	2	6	3	6	3	3	2	4	—	3	1	5	2	1	—	1	—	1	1	—	—	—	—	1	—	—	—	—	—
AB	1	2	2	—	—	4	2	3	5	11	5	15	11	17	9	8	5	15	3	6	8	6	7	6	4	1	3	1	1	2	—	1	—
1	1	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

RATE OF LEAF PRODUCTION

TREATMENT
A 7 leaves/6 months,
B 5 leaves/6 months
AB 9 leaves/6 months
1 3 leaves/6 months.